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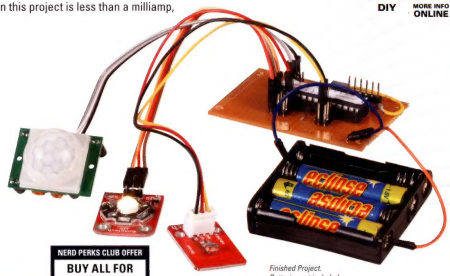

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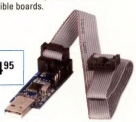

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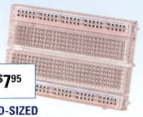

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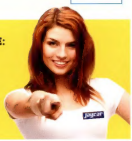

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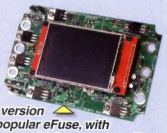

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Publisher & Editor-in-Chief
Leo Simpson, B.Bus., FAICD

Editor
Nicholas Vinen

Technical Editor
John Clarke, B.E.(Elec.)

Technical Staff
Ross Tester
Jim Rowe, B.A., B.Sc
Bao Smith, B.Sc

Photography
Ross Tester

Reader Services
Ann Morris

Advertising Enquiries
Glyn Smith
Phone (02) 9939 3295
Mobile 0431 792 293
glyn@siliconchip.com.au

Regular Contributors
Brendan Akhurst
Ian Batty
David Maddison B.App.Sc. (Hons 1), PhD, Grad.Dip.Entr.Innov.
Associate Professor Graham Parslow
Dave Thompson

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Editorial office:
Unit 1 (up ramp), 234 Harbord Rd, Brookvale, NSW 2100.
Postal address: PO Box 139, Collaroy Beach, NSW 2097.
Phone (02) 9939 3295.
E-mail: silicon@siliconchip.com.au

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Publisher's Letter

Incat's world-class really fast ferries – designed and built in Tasmania

Back in April this year I was fortunate to visit Incat's impressive production facilities in Hobart, Tasmania, as the guest of Gary Johnston, of Jaycar Electronics. This was actually an extension of a trip with Gary and Dick Smith to attend the 35th birthday celebration dinner of the Historical Radio Society in Melbourne where Dick Smith was the keynote speaker at the event. That was a most enjoyable experience but the trip to Incat was a truly memorable bonus as we were given an extensive guided tour by the founder of Incat, Bob Clifford.

While the article starting on page 16 of this issue attempts to describe the scale of the overall production facilities and gives some dimensions of the vessels that we saw being built, being on-site gives an entirely different impression. These vessels are huge. For a start, they are 32 metres wide; that's over 100 feet in good olde Imperial units. This is the same beam dimension as ships which comply with the so-called Panamax standard, allowing them to – just – pass through the Panama Canal!

Even standing outside these ferries really doesn't drive home just how big they are. To fully appreciate their size, you have to walk the length of the ship on the various decks, particularly the one which accommodates the massive semi-trailers and which allows them to turn around at the end of the deck and drive back out!

That these vessels are also designed and completely manufactured in little old Tasmania with a highly skilled and highly motivated workforce is truly gratifying. It shows that Australian companies really can compete with the rest of the world, in spite of our high labour costs and distance from the main markets in Europe.

LEDs are now the overwhelming choice for domestic lighting

If you have not recently visited some newly constructed homes or apartment blocks, you may not have realised how ubiquitous LED lighting in homes has now become. In virtually every new home, the standard lighting source is the flush-mounting LED downlight, designed to fit into a 90mm circular cut-out in plasterboard ceilings. A typical 4-bedroom home could easily have 60 or more of these downlights. The once popular 12V halogen downlights and those horrible compact fluorescent lights have gone but so has any other form of incandescent (halogen or otherwise) and fluorescent lighting too.

This is good from an energy perspective, because it means that the lighting energy limits in Australian building standards are now fairly meaningless. People can have as much lighting in their homes as they want, without worrying about energy cost, climate change or any limits placed on them by overbearing government regulations. That is not to say that everything about LED lighting is good – some of these fittings do generate a lot of interference and there is no indication when you buy a LED fitting that it might be a problem.

Of course, you need not be confined to downlights for domestic lighting. There is now a LED equivalent for virtually every conceivable lamp shape and function with the only notable exception being those lamps exposed to high temperatures, such as those used in ovens. The only drawback with some LED lamps is that they may not be suitable for bedrooms and in living and dining rooms, particularly those that are cool white.

Some people may find their light too bright and harsh. In that case, they would need to choose warm white for those rooms and even then, probably need dimmers in each bedroom and living room. And the old faithful dimmers which worked OK with incandescent may not be suitable, as we discuss in the article starting on page 24 of this issue.

Leo Simpson

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True confessions and the HMV Little Nipper

With regard to the Vintage Radio article on the HMV 64-52 Little Nipper restoration in the May 2017 issue, and my letter on the topic in the June 2017 issue, while I realise we are dealing with restoration rather than improvements to the original, I would like to make the following comment regarding the loop antenna.

After the loop antenna was wound on a mandrel, a current was then passed through it, of just sufficient strength to melt the wire's plastic covering and make it rigid to mount on the plastic back.

With the benefit of hindsight, a better grade of plastic covering could have been used, as the "welding" of the cheap plastic increased self-capacity and lowered the "Q", thus affecting sensitivity and selectivity.

Neville Snow,
Burwood, NSW.

Cathodes don't glow; filaments do

I am writing about the HMV 64-52 Little Nipper radio featured in the Vintage Radio pages of the May 2017 issue (**www.siliconchip.com.au/Article/10657**).

I must have refurbished at least a dozen of these. I did a double-take at the statement: "I noticed that the cathodes were glowing all but the 6BA6 valve". Oops! Cathodes don't normally glow; filaments, heaters and globes do; plates may, but only when things are not right.

Also to be noted in that series is the screen resistor in this set, R6. Originally that was 2 x 22kΩ, 1W, in parallel. Later versions used a single 10kΩ resistor. As the dissipation exceeds 1W, that resistor often fails.

I actually have one of these sets. Its only failure since refurbishing, ages ago, was a sudden and massive "off-frequency" event. That was truly a bug in the system. A large arachnid had perished on the top of the oscillator coil!

Regarding the author's comment that powering up that 64-52 set "cold" (ie, without inspecting it first) was a bad idea; I have to agree.

One person that I know of decided that as his Dad had restored the set he was selling, it could be powered up to demonstrate for a buyer. That resulted in the immediate and spectacular demise of one type 80 valve. So he then replaced the valve and powered it back on again!

Fortunately, when the plates went red, they shut it down and the valve survived. However, inside the pan and on the floor of the cabinet was an impressive powder-coating job, done by the first unit to fry.

Marc Chick,
Wangarratta, Vic.

Editor's note: keep in mind that some battery-operated valves use a directly heated cathode and in this case, the cathode would actually glow (albeit very faintly).

Synchronous inertia for grid stability is currently our best bet

I would like to comment on the recent letter from Dr Kenneth Moxham (Mailbag, February 2017), in which he presumes to discuss alternative methods for achieving grid stability. Since the publication of his letter, Victoria's Hazelwood power station has been shut down and the power crisis in South Australia continues.

While some might believe that this is a time to discuss alternative generation technologies, the average person in South Australia, faced with the prospect of yet another blackout at any time, quite reasonably wants the problem fixed and preferably now.

Those of us who are professional engineers have a clear responsibility to discuss solutions that can be implemented immediately, not those that might be available only far off into the future.

Discussion should be restricted to those means that use readily available, off-the-shelf equipment. Furthermore, when we speak as professional engineers, we need to indicate that we have taken due regard of the published literature. I mention these points because I note that Dr Moxham signed his letter as a professional engineer.

I discussed the matter of synchronous inertia in an earlier letter (Mailbag, December, 2016). I cited a paper by a Marcelle Gannon (2014) because it addressed this very issue: the then-emerging stability issue on the Eastern Australian grid.

In this paper, not only are the mechanisms that contribute to grid stability discussed in considerable detail but work on potential alternatives to the use of rotational inertia is cited (Section 3.4.4).

Furthermore, Table 2 and Section 5.2 of the paper examine various alternative ways for providing both conventional synchronous inertia and its replacement "synthetic inertia".

The paper also provides an excellent review of work internationally, and within Australia by the AEMO, the AEMC, and other professional organisations. Dr Moxham might also like to read: **http://siliconchip.com.au/l/aacz**

Clearly then, both the relevant professional bodies and the grid manager have been actively discussing the emerging stability issue and how to tackle it for some years. This contradicts Dr Moxham's concern that "no one seems to be talking about controlling the system in another way so the stability is not compromised" or that "no one seems to be thinking outside the square".

Dr Moxham states, categorically: "It is wrong to suggest that the rotational inertia that comes from the kinetic energy of the spinning mass is the source of stability under fault conditions." Perhaps Dr Moxham meant to include the words "only possible"

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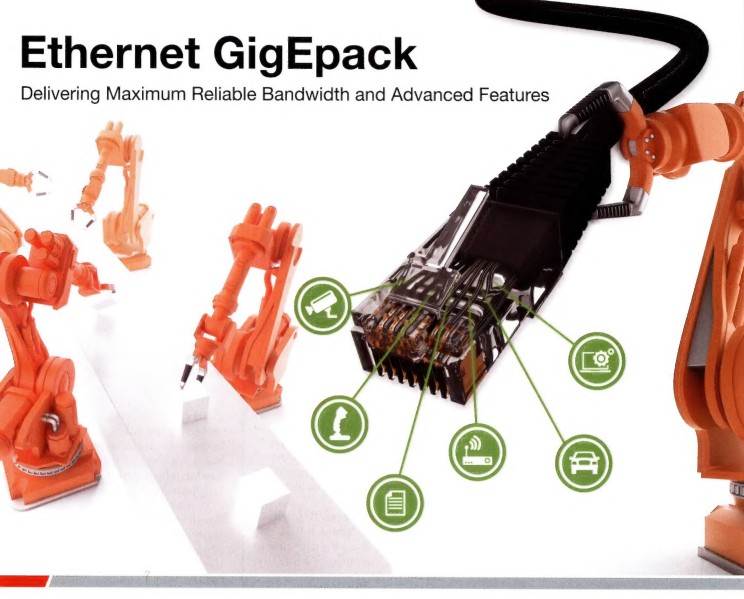

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Mailbag: continued

LED downlight interference problems solved

Some time ago, I wrote to you regarding LED lights that were installed in my kitchen interfering with the TV reception on my Topfield set-top box (STB) feeding a Sony rear projection analog TV. Until now, we just had to put up with it.

The Topfield STB gave up the ghost and as they're out of business, I bought a new STB, a Teac, for $58.00 rather that get a new TV, since a similar one to what we have would cost approximately $1500.

As the STB was brand new and the problem was still there, I rang Teac's help line and one of their "technicians" suggested some new automated channel searches that did not fix the problem; he said that the STB was OK.

So I contacted a local antenna company and their representative knew of this problem. Using a signal strength meter, he found that the LEDs in the kitchen have a noise/hash output that affects TV broadcasts that are around 150-170MHz, to which the Teac STB was tuned, using the auto search.

He manually tuned the TV stations in the STB to UHF frequencies above 550Mhz — problem solved! The Teac "technician" made no such suggestion.

These LEDs also affect FM broadcasts above 100MHz and I use an analog TV aerial that is wired to the antenna system within our home for picking up FM broadcasts.

The antenna man said that as I was using the analog antenna to supply the FM receiver, to leave it there, otherwise he would suggest I remove it.

The offending LEDs came from Kogan, and another LED installed in the room with the TV, a Philips one, has very little or no hash output. So I'm going to ditch the Kogan LEDs and replace them with Philips units, despite the TV tuning being OK anyway.

Apparently, some LEDs have "No RF interference" printed on the packaging but the Philips one doesn't have this. Anyway, looking out for LEDs that are marked might be a good idea in future.

The average punter wouldn't have a signal strength meter but if you know the solution, you can tune to the higher TV frequencies manually.

Ian Stewart,
Glenhaven, NSW.

between the words "the" and "source".

As this last statement of Dr Moxham's stands, it is quite simply wrong. Every grid systems engineer around the world will disagree with it.

Again, Gannon's paper, Section 3, provides a more than adequate explanation as to how a network of conventional generators, each with its inherently large rotational inertia, provides more than sufficient synchronous inertia, hence system stability, and therefore protection to deal with transient fault conditions.

Also importantly, in conventional power stations, synchronous inertia is already available, essentially "free", as its provision is an inherent part of the generator design.

As a young engineer, I very quickly learned that if I thought to criticise any engineering work, I was required to provide a costed alternative, accompanied by a complete description of how it would work.

That is an essential requirement of one's Engineers' Code of Conduct. By contrast, Dr Moxham provides no suggestion as to what actual, available technology (his "other ways"), might replace conventional rotational inertia.

Tantalisingly, he provides no suggestion as to how those whom he criticises might "think outside the square". If he had, as Ms Gannon, for example, has done, he might well have found that proposed alternatives are not only untested, but are also unrealistically expensive.

For example, presently fashionable as a "solution" is battery storage. How many batteries? For SA's needs, my colleague Dr Tom Quirk has done some calculations, using real, live, AEMO grid data. The outcome? Well, it's rather more than the couple of AAA cells needed in your TV remote.

To support a 100% renewables scenario just for South Australia, for example, Dr Quirk estimates a Li-ion battery requirement of some 2.1 million tonnes. The cheaper Lead-Acid route would require some 7.5 million tonnes of batteries. Cost? Oh, a mere $60-90 billion. Simple really.

This calculation does not address the necessary battery replacement inventory or the generation to charge it, all of which adds to the cost. It also does not discuss the very substantial CO_2 emissions cost in such as the mining and milling of the ores to obtain the lithium or the lead, and in the battery fabrication. See **http://siliconchip.com.au/l/aacy**

Dr Quirk also investigates the (quite mad) scenario that includes battery storage, presently on offer from the South Australian government, at **www.onlineopinion.com.au/view.asp?article=18948** Clearly, this battery-powered route is going nowhere.

Is there an immediate solution to South Australia's ongoing grid stability issues and skyrocketing power prices? As I said in my earlier letter, the Federal Government should abolish the MRET subsidy scheme immediately.

Removal of the very lucrative MRET subsidies would remove the price distortion in the electricity market that at present has the absurd side-effect that it forces out schemes such as clean-burning gas-fuelled power stations (for example, Pelican Point).

Also necessary is that the South Australian government finds a replacement for the now demolished Port Augusta Power Stations, for the reasons earlier discussed. South Australians, and in particular residents in northern parts of SA (such as Port Lincoln, Ceduna, Whyalla and Roxby Downs) who have experienced power outages of as much as a week at a time might then see the restoration of a secure electricity supply.

The Hazelwood power station must also be restarted. Hazelwood's closure not only places further risks in the way of grid stability, its lack will cause a large jump in prices, particularly for

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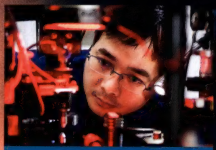

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Mailbag: continued

South Australians, dependent as they are on Victorian power via the interconnectors, as Hazelwood's output will have to be replaced by more expensive gas-fired generation.

Let Dr Moxham understand that where he signs a letter as a professional engineer, he is required to discuss the detail of any alternative "solutions" that he might propose, to provide the necessary literature review, and to provide detailed costings. To merely mention that alternatives might exist does not make them viable solutions.

Paul Miskelly,
Mittagong, NSW.

Virtins software activation

Further to your publication of my letter regarding a problem with the Virtins multi-instrument software (page 5, June 2017), I was contacted by David Wang of Virtins. He requested my site code and MID and when I provided them he responded with a new activation code which worked, so the software is now restored to operation.

Thank you for publishing my letter which was apparently instrumental in clarifying the logical course of action.

Barrie Davis,
Hope Valley, SA.

Improvements can easily be made to High Performance 6GHz+ RF Prescaler

The article on the 6GHz+ RF Prescaler project (May 2017; www.siliconchip.com.au/Article/10643) contains contradictory statements. Towards the end of the section headed "Output Stage", it says the output impedance is 75Ω, the output voltage swing is 2V peak-to-peak but only about 300mV when terminated with 50Ω or 75Ω.

If the output impedance were actually 75Ω, terminating it with an equal value would exactly halve the output voltage. This much larger observed change implies a much higher output impedance.

A glance at the circuit diagram makes it obvious that the output impedances are actually 300Ω.

Q1 and Q2 form a long-tailed pair and act as a current source, presenting a very high (ideally infinite) impedance, so the output impedances are determined solely by the resistances between CON1 and CON2 and ground. It is not clear that the 100Ω resistors serve any useful purpose, their impedance is negligible in comparison to that presented by Q1 and Q2.

Closer examination reveals a further anomaly: for an ECL output-low level of nominally 1.95V, the Q1/Q2 emitter current should be approximately 8.8mA, which is switched alternately to the two 300Ω output resistors, giving output voltages of 2.7V into an open circuit, 528mV into 75Ω and 378mV into 50Ω. The observed 2V unloaded output is clearly very low.

The reason for this is that, with its base at 1.95V, Q1's emitter will be at about 2.1V and, with the given 400Ω collector load, Q1 will saturate (the same applies to Q2). When saturated, the predicted open-circuit output voltage is 2.05V, in good agreement with that observed. Transistors are slow to recover from saturation so it is best avoided in high frequency circuits. Output terminations below 220Ω will prevent saturation of Q1/Q2.

To properly match 75Ω (or 50Ω) lines, the 300Ω resistors could be replaced with 75Ω (51Ω) resistors (or perhaps one of each), giving open circuit output of 660mV (450mV), and 330mV (225mV) into matching loads. These levels could be increased by reducing the value of the 330Ω Q1/Q2 emitter resistor.

Anthony John Ellis,
Wellington, New Zealand.

Editor's note: your analysis is correct. This part of the circuit was based on a number of previous prescaler circuits, none of which were criticised as being incorrect, although they clearly were.

The assumption was obviously that the output impedance of Q1/Q2 was zero, so the 100Ω and 300Ω resistors in parallel gave an output impedance of 75Ω. But as you point out, this assumption was wrong because of the high collector source impedances of transistors Q1 & Q2.

Your suggested changes can be made by simply substituting 0Ω resistors for the 100Ω resistors and 75Ω resistors for the 300Ω resistors.

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On page 104 of this issue we have published Notes & Errata covering this suggested change. Thank you for bringing it to our attention.

Forcing children to learn robotics may lead to frustration

The article on Industrial Robots (May 2017) attracted my attention. Dr Maddison has produced another fine overview of a subject and it included quite a few details that I was not aware of.

It reminded me that sometimes you don't know what you don't know. I have spent considerable time looking for information on robotics and still didn't know about all the robots Dr Maddison wrote about.

During the past year, I have been looking at scanned copies of early magazines and books etc at **archive.org** I am just amazed at how much information is available.

I am not just referring to programs and robotics; the same applies to electronics and mechanics. The material might be old, but quite a number of articles etc have provided me with the clues to solve problems.

For example, there are quite a few issues of Radio Electronics available at: **https://archive.org/details/radioelectronicsmagazine**

Unfortunately, it takes a lot of time to search through the magazines.

To change the topic, I would like to comment on the action plan of the Queensland government to require all students to study coding and robots. This was confirmed with a consultation report dated 14 October 2015.

I had to study programming when I was studying for a Mechanical Engineering degree part time and failed it miserably twice before passing.

It was the root cause for me terminating my studies as I hated it. It wasn't until I bought a Sharp PC1500A pocket computer that my attitude completely changed. The computer was programmed using BASIC and very quickly I was able to understand how programming worked. I have never looked back.

Some years later, I was working in the School of Civil Engineering and saw a group of students in the lab who were very angry about something.

I asked them why; they told me that a new subject had been created in which they had to learn about stepper motors plus (I assume) the electronics and programming. They absolutely hated the idea. They had chosen the Civil Engineering degree because they were not interested in electronics. They were interested in buildings, roads, dams and earth works.

I have no doubt that there will be students who will thrive in the environment set up by the Queensland government but I also have no doubt that there will be many more students who will reject everything to do with coding and robotics (and electronics). I have a lot of sympathy for them.

I also have a lot of sympathy for those who are lured into robotics without being told how difficult it would be. I saw this a lot at university. Students were coerced into engineering without being told about the heavy maths and science that they would need to know and they suffered. Hard core robotics is far worse than any single science because it requires knowledge covering so many different areas.

Also I am sure that the kids will be required to learn one of the approved

Solar hot water heater controller wanted

In your Publisher's letter in May, you mentioned the possibility of a project which would operate a pool pump and salt water chlorinator when solar power was available. I'm very interested in that project as I'm building a house in Victoria and attempting to work out the most economical way to provide hot water.

My feedback from plumbers is that solar hot water systems are quite hit and miss affairs in Victoria. The people I talk to say they rarely understand why one system works and another doesn't (same brand).

So I am looking at a heat pump water heater which looks quite promising, but for best performance should run on solar generated power and not power from the network. My thoughts on a controller are that it should be able to:

- Accurately determine the time (GPS) for tariff knowledge and solar prediction.
- Determine the Solar power input and be able to disconnect the load should the Solar input drop below the load requirement.
- Have spare sensor inputs that determine the heat input required to ensure sufficient hot water is available or decide that no extra heating is required.
- Be user programmable to refine the control characteristics.

This would mean opening the design to be more user-configurable and making the controller user programmable. I look forward to seeing what you can come up with.

Tony Riedle,
via email.

Comment: one of our staff members has a heat pump solar system and it failed just before the 5-year warranty ran out (fortunately). We also would be concerned about the noise from these units as the compressor runs. His unit was very noisy before it failed and now, some 18 months later, the replacement is heading in the same direction.

If you did decide on the heat pump option, we would be inclined to run it from the "controlled off-peak" output of your smart meter as the default option but have a controller (our design) switch over to solar power during the day.

This could work well if you use most of your hot water in the morning – solar will bring the tank back up to the thermostat setting.

If you have showers in the evening, that concept won't work so well. In that case, having a webserver which would allow you to intervene (depending on weather or other variables) might be a useful addition.

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12SB3/6P	12	30	166	126	175	175	10.1	M5 Bolt & Nut	Dual Purpose
12SB3/4C	12	34	197	131	159	170	10.5	M5 Bolt	Dual Purpose
12SB3/6C	12	36	197	131	159	188	10.7	M5 Bolt	Cyclic
12SB4/6CL	12	40	199	166	171	171	13.1	M5 Bolt	Dual Purpose
12SB4/6C	12	50	198	166	171	171	14.3	M5 Bolt	Cyclic
12SB5/6CL	12	55	226	135	207	214	17.0	M5 Bolt	Dual Purpose
12SB6/6CL	12	65	350	166	174	174	21.6	M5 Bolt & Nut	Dual Purpose
12SB6/6CL-FR	12	90	260	170	202	205	24.0	M8 Bolt	Dual Purpose
12SB11/6CLS-FR	12	110	306	169	209	214	36.5	M8 Bolt	Dual Purpose
12SB12/6CL-FR	12	120	338	170	212	215	32.5	M8 Bolt	Dual Purpose
12SB14/6CL-FR	12	140	302	170	276	276	43.0	M8 Bolt	Dual Purpose
12SB18/6CL-FR	12	180	332	170	276	276	46.0	M8 Bolt	Dual Purpose
12SB22/6CL-FR	12	220	522	238	219	222	68.5	M8 Bolt	Dual Purpose
GEL Type									
12GB7C	12	7	151	65	94	102	2.7	F1 (Faston 187)	Cyclic
12GB12C	12	12	151	98	93	98	4.0	F2 (Faston 250)	Cyclic
12GB17C	12	17	181	76	167	167	6.3	M5 Bolt & Nut	Cyclic
12GB24C	12	24	166	175	125	125	9.5	M5 Bolt & Nut	Cyclic
12GB30C	12	30	197	131	159	159	12.1	M5 Bolt	Cyclic
12GB50C	12	50	198	166	171	171	14.5	M5 Bolt	Cyclic
12GB55C	12	55	229	138	207	214	17.0	M5 Bolt	Cyclic
12GB65C	12	65	350	166	174	174	23.9	M8 Bolt & Nut	Cyclic
12GB75C	12	75	260	170	202	205	24.9	M8 Bolt	Cyclic
12GB100C	12	100	330	170	212	215	34.0	M8 Bolt	Cyclic
12GB150C-FR	12	152	500	110	208	208	50.0	M8 Bolt	Cyclic

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programming languages and BASIC will not be included. I can see a repeat of what happened to me.

Finally, I saw the question in Ask Silicon Chip, May 2017, on page 110 where K. S. requested some help to control the speed of a 180V DC motor. I needed variable speed many years ago for some pump experiments at university and I decided to use large variacs with DC motors. When I asked a local manufacturer for suitable motors, he specified 180V motors with shunt field windings.

I queried him about the voltage but he assured me that was the correct voltage for the rectified AC. I later found a small motor and controller for a different project and that motor was also rated at 180V. I thought that I would tell you about my experience because there was some doubt in the Silicon Chip reply about the motor being suitable for 230VAC operation. Note that no capacitors were required.

George Ramsay,
Holland Park, Qld.

Comment: your remarks about 180V motors are pertinent. Any power or kitchen appliance with a built-in speed control will employ a 180V motor. However, the caution about the motor having suitable winding ratings to work at the peak voltages from our mains supply is still relevant.

Measuring lamp brightness with a smartphone

Recently at work I had to make some leads to plug into automotive cigarette lighter. It was really time-consuming task to get all the wire strands into the screw terminal and make the work profitable. Later that night, while at home I was thinking about it. My thought was: what if our suppliers are supplying metric wire but components like plugs and sockets are made with tooling using Imperial measurements?

At home, I replaced a 23W mercury-filled energy-saving lamp. The lamp has same shape as a water jug element; it was supposed to be the equivalent of a 100W incandescent lamp. I replaced it with a 13W LED lamp. Since then I have been blown away by the extra brightness of the LED lamp.

I wonder why cell phone manufacturers have not put a lux meter into their phones so we can check out these things more easily. In physics class, one experiment was to get a piece of paper and put an oil patch on it.

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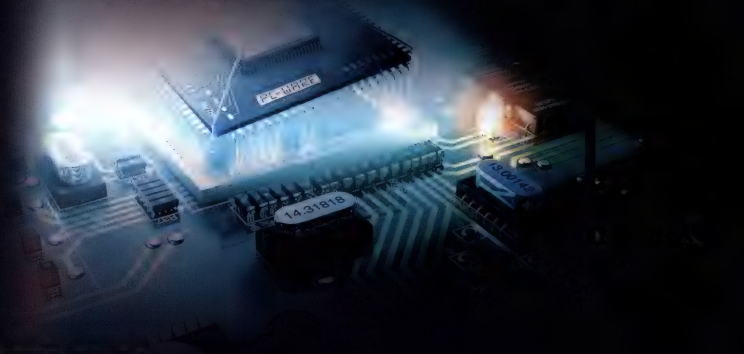

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Microbridge serial interface isn't compatible with LCD BackPack

I really loved the Microbridge article in the May 2017 issue. I know that SILICON CHIP is not the originator of this project however I do have a bit of an issue. The pinouts for the serial connectors are different between the Microbridge and both the original BackPack and the BackPack V2.

The connections on the Microbridge are +3.3V, +5V, RX, TX, GND while the BackPack uses +5V, TX, RX, GND. If I am to use both, they would require different connectors for the USB to TTL adaptor. I know that the Microbridge can be plugged into the BackPack for programming, but if the BackPack is installed into a box, like I have, then there is not enough room to plug in a Microbridge.

Mike Flor,
Wyongah, NSW.

Comment: unfortunately, we didn't notice that difference in pinouts. If we had, we could have modified the Microbridge circuit and PCB prior to publication, to make it plug-in compatible with the BackPack projects. Sorry!

Solution to losing the mouse

In a recent article about the Philips 43-inch 4K monitor in the March 2017 issue, the reviewer mentioned the difficulty of locating the mouse cursor. Windows has the ability to change cursor behaviour under Mouse Properties→Pointer Options tab→Visibility. I have mine set to Pointer trails Long. It helps heaps as soon as you start moving the mouse.

Warren Hudson,
via email.

As you move the sheet between two lamps, you can clearly see when the brightness is the same on each side of the paper and thus determine which is brighter, by the distance from the lamps (ie, the paper will be further from the brighter lamp).

Eric Richards,
Auckland, New Zealand.

Editor's note: there are a number of "lux meter" apps for Android and we would assume for iPhone too. Presumably, they use the light meter built into most cameras, which is used to determine the aperture and shutter speed for taking photos. We would treat measurements made with these apps as being approximate but they do seem to work quite well for comparing the brightness of various lamps.

Having said that, you have to be cautious in making comparisons between lux measurements of different lamps because these are spot measurements; two lamps with an identical light output in lumens could give different lux measurements depending on how focussed their beams are.

Lamps with very focussed beams tend not to be less useful for domestic lighting (with certain exceptions, ie, where you want spot lighting) but do give higher maximum readings on a lux meter.

As for your comment about fitting wire into screw terminals, clearly there are some metric/imperial mismatches but given the large variety of wire thicknesses available, the main issue is more likely to be that the socket was intended to be used with thinner gauge wire, either because it isn't intended for high current use or to save money.

An interesting book on regenerative braking

I have been following the letters on regenerative braking, starting with the original request in Ask SILICON CHIP on page 99 of the January 2017 issue and following on in the March and May Mailbag sections.

For those with an interest in regenerative and rheostatic braking there is a really good book about it called "The Regenerative Braking Story" by Struan JT Robertson and John D Markham, published by the Scottish Tramway and Transport Society. I purchased it from Camden books in the UK on the basis of the review in their catalog and it more than lived up to their accolades.

It is currently available from Amazon at **http://siliconchip.com.au/l/aad0** It's based around trams and trolley buses. I liked it because it blended the technical with history and has lots of pictures and circuits.

Neil Bruce,
Elphinstone, Vic. SC

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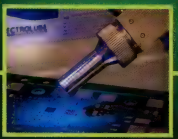

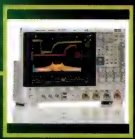

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You may not have heard of Incat, a family-owned company in Hobart, Tasmania, but the chances are high that you've seen some of their products. They build a variety of aluminium vessels – but their big, fast, ocean-going wave-piercing catamarans are recognised as world leaders.

The first thing that strikes you about Incat Tasmania is the sheer size of the assembly plant. The address is quite deceiving – 18 Bender Drive, Derwent Park (a suburb of Hobart on the Derwent river) – it almost sounds like a suburban house block! But as you travel down Bender Drive towards the Prince of Wales Bay, north of Hobart, you realise that Incat is no backyard operation. It's huge!

Then again, simultaneously building several vessels up to 120m long means it's not likely to fit into a backyard shed! And the fact that there are five huge undercover construction buildings along with a large range of ancillary services suggests it's going to occupy a lot of area. And it does – have a look at the site map/photo and you'll see what we mean. There's over 70,000 square metres of production halls alone, spread across five massive buildings.

Perhaps an introduction to this Australian success story might be in order here. Incat Tasmania is acknowledged as the world leader in the manufacture of high-speed wave-piercing catamarans. Not just a leader, but the leader!

Wherever you go in the world, you're likely to spot (or maybe travel on) an Incat Tasmania vessel – whether you're taking a car or lorry across the Baltic Sea or Mediterranean, traversing the Thames in a high-speed passenger ferry, flitting between ports in Asia or South America, swapping crews and equipment on off-shore oil rigs . . . or even taking a quick trip (sometimes very quick!) on Sydney Harbour.

As of 2017, they've built 88 craft, ranging from a 15m barge and 24m harbour ferries right through to 112m wave-piercing catamarans (WPC) intended for open water. The last one was launched in April and headed for Denmark where it was scheduled to begin service on June 1.

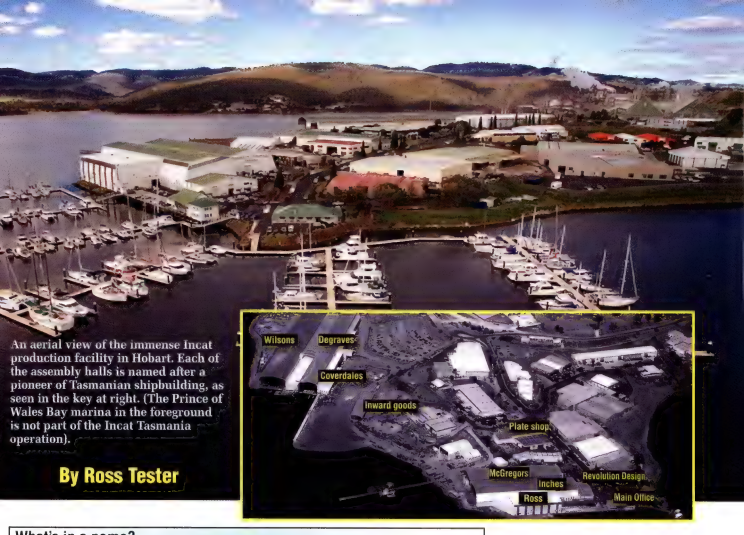
Construction of hull no. 89 was started just a few weeks ago. It is scheduled for delivery in late 2018. Designers are currently looking at even larger vessels, up to a 130m WPC.

Incat are far more than just "shipbuilders", however. They design the craft from the keel up, using a specialist (but in-house) team called "Revolution Design". And their designs are just that – revolutionary.

Revolution Design have naval architects, engineers and designers, working in conjunction with the concept and creative team to develop and refine vessel design.

Incat's latest generation craft are capable of carrying almost 100% of the ship's own weight – they're the only ship builder in the world to achieve this – making Incat craft very popular with operators who need to maximise payloads to gain an edge over considerable opposition.

This, coupled with fast speeds, shallow draft, fast turn-around in port, flexibility in vehicle deck layout, passenger



An aerial view of the immense Incat production facility in Hobart. Each of the assembly halls is named after a pioneer of Tasmanian shipbuilding, as seen in the key at right. (The Prince of Wales Bay marina in the foreground is not part of the Incat Tasmania operation).

By Ross Tester

What's in a name?

If you Google "Incat", you're likely to find two companies answering to that name: **Incat Tasmania** (**www.incat.com.au**) and another (unrelated) company, **Incat Crowther**, based in Sydney.

Incat Tasmania (short for the "International Catamarans" group) *design and build* ships in Hobart; Incat Crowther design ships but have others build them under contract (often overseas).

comfort, minimal crewing requirements and reliable and economic operation further add to their appeal around the world.

For example, many roll-on, roll-off vessels require access ramps at both the bow and stern, so large trucks/semi trailers etc can get on and off without a lot of manoeuvring. Incat's 98m ro-ro vessels only have stern ramps – but their internal design allows for a semi to turn 180° on the vehicle deck, meaning a lot more flexibility in ports.

But we're getting a little ahead of ourselves.

Incat Tasmania's past

The company's roots can be traced back to the early 1970s, when Bob Clifford (now Robert Clifford, AO, chairman of Incat) formed the Sullivans Cove Ferry Company (SCFC) to build conventional steel mono-hull ferries for Hobart's Derwent River.

The timing was rather opportune, because on January 5th, 1975, the bulk ore carrier Lake Illawarra crashed into the supports of the Tasman Bridge (the only link between Hobart and its eastern suburbs), bringing down part of it. In the two years following, SCFC ferried more than nine million passengers across the Derwent while the bridge was replaced.

After the bridge re-opened, the company now called International Catamarans Pty Ltd (Incat) started construction of fast ferries, made exclusively of marine-grade aluminium alloy. They had done extensive research and development on the merits of aluminium construction, which is one third the density of steel.

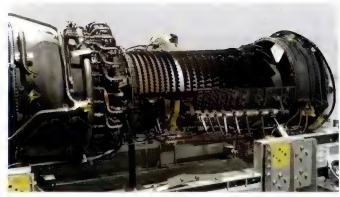
On the downside, aluminium fabrication – welding, in particular – requires much more skilled craftsmen than does conventional (steel) construction. Getting those skilled craftsmen in the early days was a significant problem, later overcome to a large degree by co-siting a Tasmanian TAFE college which specialised in the craft. Now called Tasmania Polytechnic, this continues, highly successfully, to this day.

In 1983, they built a prototype 8.7m craft called "Little Devil" and proved the wave-piercing concept. This was followed by a full-sized (28m) wave-piercing vessel, the Spirit of Victoria, in 1985 and "Tassie Devil" in 1986.

The R&D put into these vessels is still in evidence today, although a huge amount of R&D has continued and will continue into the future. And the size of the craft has significantly increased.

But (if you'll excuse the nautical pun) it certainly hasn't always been plain sailing for Incat Tasmania. Following the global financial crisis, orders dropped alarmingly, putting the company into severe financial difficulty. It had completed

The world's fastest passenger ship, the 99m Incat No. 069 *Francisco*, in service between Argentina and Uruguay. Lightly loaded, it has been measured at 58.1 knots – considerably more than 100km/h. With a full load of vehicles and passengers AND running at only 90% engine capacity, it cruises at 49 knots (90km/h+).



And this is what powers it (or more correctly two of what power it!): twin 22MW GE Energy LM2500 marine gas turbine engines driving Wartsila LXJ 1720 SR waterjets. This engine is just over 4m long x 1.5m diameter. Incat believe that the Francisco is capable of even faster speeds with less fuel on board, in calm waters.

vessels it couldn't sell and others, being built on spec, had no sign of likely purchasers.

In fact, Incat would have gone under if its then bankers had their way. But with help from the Tasmanian government, a relatively small amount of restructuring and redundancies (far less than the bank demanded), coupled with the very timely sale of two completed craft, Robert Clifford and his team were successful in trading their way out of difficulties, in the process becoming more structured and better managed. And they changed banks!

Jet power – and a world record

While quite a number of craft are constructed using the traditional propellor and rudder method (eg, the new inner Sydney Harbour ferries), the larger Incat vessels – especially those intended for offshore use – are powered by marine water jets. These have several major advantages over propellers, not the least of which is incredible manoeuvrability. Because the jets can be angled to wherever needed, bow thrusters are not required (the jets can push the vessel sideways). This also allows a shallower draft than vessels fitted with propellers and a rudder.

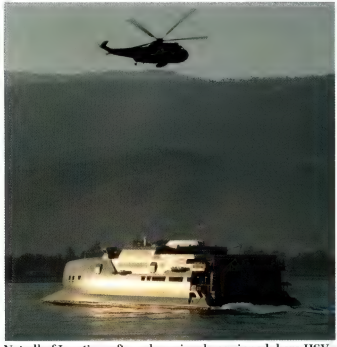
And then, of course, there is the rather dramatic speed capability.

An innovative Incat ferry, the world's first LNG/dual fuel model, holds the record for the fastest large passenger vessel in the world – the 99m ferry *Francisco*, lightly loaded, has been officially "clocked" at 58.1 knots (107.6km/h).

Of course, there are many speedboats and other craft capable of this speed . . . but not many of them can carry 1000 passengers **and** 150 cars in superb comfort!

This ferry, launched in 2013 and named in honour of Pope Francis (originally from Argentina) is now in service on the River Plate between Argentina and Uruguay. It easily achieves a regular running speed of 49 knots at 90% power from its twin 22MW GE Energy LM2500 marine gas turbine engines, driving Wartsila LJX 1720 SR waterjets. For those without a nautical "bent", 49 knots is over 90km/h!

Speaking of those engines, as gas turbines, they're a lot smaller than reciprocating engines used in many other WPCs: 4.29 x 1.52m diameter. But they gulp fuel at an



Not all of Incat's craft are luxuriously equipped: here HSV-1 *"Jervis Bay"* is fitted out for military use. She made over 100 trips between Darwin and Dili in the 1999 emergency.

Its sister ship, the *HSV-2 Swift*, was attacked with a missile attack by Houthi rebels off the coast of Yemen in October 2016. Early reports had it sunk but it was only seriously wounded!

In this photo of the construction of the *Express* 2, you can clearly see the third hull. Normally it sits above the waterline but in big seas, helps smooth out the pitching action and acts as a "shock absorber".

The 20-cylinder MAN 28/33D engine (10 per side in "V" formation) is shown here installed in the next Incat WPC to come off the line (the *Express 3*) – but the engine is too massive to get it all in the one photo!

enormous rate – another 98m Incat vessel, built and configured for military use, is quoted to consume 180 litres per nautical mile at just 35 knots! We've shown a photo of one of the gas turbine engines opposite.

Marine diesels, too

Other wave-piercing catamarans built by Incat use more conventional high-speed marine diesels – still immensely powerful, still driving waterjets.

For example the four MAN 28/33D STC 20 cylinder 4-stroke diesel engines in the 112m Express1 (2012), and Express2 (2013) are each rated at 9000kW, while the 109m Express 3's engines are rated at 9100kW, the engines are almost 4m high, 2.5m wide and 8m long and weigh over fifty tonnes. The name deciphers as 280mm bore, 330mm stroke, while STC stands for sequential turbo charging.

With a maximum engine speed of 1000 RPM, a bore of 280mm and a stroke of 330mm, they each consume around 1700kg of fuel per hour . . . and yet are claimed to be the most powerful and fuel-efficient 1000 RPM diesel engines in the world. Boat speed (loaded) is 40 knots while unloaded they can achieve 47 knots.

Incidentally, build time of the Express 3 from laying the keel in Hobart to delivery to its owners, Molslinjen (Denmark) via the Panama Canal was just 491 days. Express 3 entered service on June 1st.

And another world record (or three)

The Blue Riband (or more correctly titled, the Hales Trophy) is the much-sought-after world record for the fastest crossing of the Atlantic by a passenger ship. It's not only a test of speed, it's a test of endurance and reliability.

The Blue Riband dates back to the 1830s, when ships fought over the honour of being the fastest transatlantic liner. In 1935, to encourage innovation in passenger transport and formalise the Blue Riband, Harold Hales, a British MP, commissioned and donated a four foot high, heavily gilded solid silver trophy.

The last big liner to win the trophy was the *SS United States* on its maiden voyage in 1952, averaging 35.59 knots.

Now Incat ships hold that record – in fact, the last three times the record has been broken were by Incat vessels, each in turn earning the right to fly the prestigious Blue Riband. In 1990 Incat's *Hoverspeed Great Britain* (hull no. 025) broke *SS United States*' 38-year-old record by three hours and 14 minutes. The 74-metre Incat wave-piercing vessel established the record of three days, seven hours and 52 minutes averaging 36.97 knots.

No ship's wheel here: the bridge of *Francisco* is very much controlled by wire – the tiny joystic near the middle of the photo is all the coxswain needs to control a 100km/h vessel.

As well as luxury ferries, Incat builds utility cats such as the 70m *Muslim Magomayev*, a fast oil well tender and crew transporter, operating in Azerbaijan.

The empty truck deck of the *Express 1*. With 4.5m headroom, it fits 23 standard semi-trailers. A second deck holds up to 150 cars; above that again is the luxuriously fitted out 1000-passenger deck, complete with restaurants, bars and both business and economy class seating.

Four DAF XF-powered semi-trailers, fully laden, sit side-by-side on the cargo deck. Unloading to empty and reloading, once docked, is remarkably fast – this vessel regularly achieves a 28 minute turnaround! Only stern ramps are needed; no reversing is required.

Eight years later, Incat's *Catalonia* (hull no. 047) on a longer route from New York to Spain raised the average speed to 38.85 knots, at the same time becoming the first commercial vessel to cover 1000 nautical miles (1850km) in 24 hours.

A month later, *Cat-Link V* (hull no. 049) broke the 40 knot barrier for the first time, taking the Hales Trophy with a record of 41.284 knots. Remember, that's the ***average*** speed right across the Atlantic Ocean!

Innovation and revolution

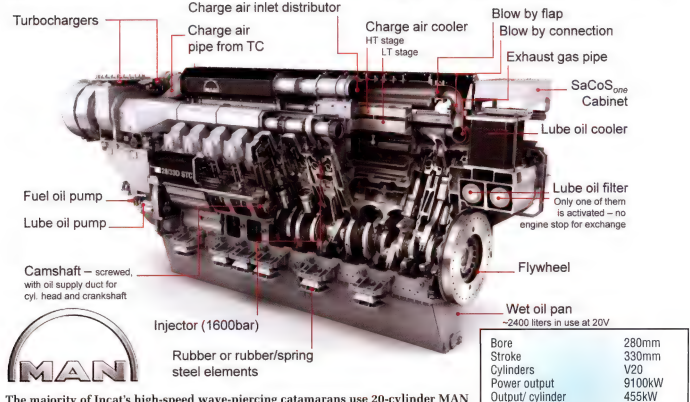
Another of Incat's "revolutionary" developments is the third bow hull. This is something of a paradox on a catamaran but it is one of the elements in Incat-built ships which results in a significant smoothing of the ride for both passengers and the ship itself.

As far as we know, this feature is unique to Incat and was added some years ago in response to difficulties with high speed operation heavy seas.

In effect, it acts as a "shock absorber" for oncoming seas. The way it works is this: in normal seas, the two "outer" hulls pierce (as their name suggests) through waves while the centre hull sits above the waterline.

In rough seas, when the ship pitches into the waves, the

MAN 28/33D STC HIGH SPEED MARINE DIESEL ENGINE (Cutaway view)



Bore	280mm
Stroke	330mm
Cylinders	V20
Power output	9100kW
Output/ cylinder	455kW
Speed	1000 RPM
Mean effective pressure	26.9 bar
Mean piston speed	11 m/s
Specific fuel consumption	188g/kWh

The majority of Incat's high-speed wave-piercing catamarans use 20-cylinder MAN 28/33D STC engines, coupled to Wartsila LXJ 1720 SR waterjets. In most craft, four such engines and waterjets are used.

Launching a 109m Cat, the *Natchan Rera*, from the huge "Wilsons" assembly hall on the Derwent river. The ship is basically complete, apart from radio and radar antennas.

As well as the new inner harbour ferries, Sydney has four Incat jet catamarans on the Manly (outer harbour) run. Two of these are 33m and two are 24m craft.

centre hull is immersed, preventing the craft from pitching as much as it normally would, therefore damping the pitching action.

The result is a much smoother ride for passengers and less stress on the ship itself.

Despite this technological advance, Incat have not rested on their laurels, continually developing and modifying the third hull – for example, later craft have more freeboard and less flat surface.

"SeaFrame" construction

Incat vessels are primarily constructed as a base vessel or SeaFrame, in line with the aviation industry's Air Frame – the structure of an aircraft exclusive of its fittings.

Building to SeaFrame enables lower production costs – it's more or less a standardised production line – and consequently lower ownership costs.

It's then up to the purchaser as to what standard and design the craft is fitted out with – everything from layout of decks, seating arrangements, colour schemes and even the number of bars and restaurants on board!

Incat have the specialists to guide purchasers through all the decisions necessary to have the craft exactly suit their requirements.

Internals

Most of Incat's fast ferries, particularly the larger wave-piercing models, are destined for operators who are looking for maximum payload capacity (both vehicles and passengers) and passenger comfort, coupled with minimum running costs, minimum turn-around in port – and of course reliability and low maintenance costs.

They're all somewhat conflicting aims, although repeat business from operators prove that Incat have achieved them. The internal photos shown here attest to the luxurious finish and feel.

Depending on the size, most vessels can handle up to 1000 passengers in aircraft-style seating, most offering two classes (business, with luxury leather seating and economy). But unlike an aircraft, passengers are free to roam about – to visit the restaurants and bars on board, watch TV, relax or view the passing scenery from the huge all-around windows. There's even a children's play area on some vessels.

Who said a ferry trip has to be boring? This is the *Neptune Clipper*, (Incat no. 076), a 35m catamaran operating on the River Thames, London.

Panoramic views from the passenger deck on the *Express 1*, with large expanses of glass coupled with comfortable, aircraft-style seating makes for a very pleasant ride.

The latest ferry to join the Sydney Harbour fleet, Incat No. 082 "*Catherine Hamlin*", a 35m conventionally propelled cat. If you don't recognise the bridge in the background . . .

. . . it could be because it was undergoing trials on the Derwent River. This photo, looking over the stern of the vessel, is in slightly more familiar surroundings.

Below them are the (usually) twin decks for vehicles, one for up to 400+ cars, the second for up to 23 full size semi trailers, with a 4.5m clearance. In some ferries a mezzanine vehicle deck can be moved up and down to accommodate differing vehicle loads.

Careful attention to design means absolute minimum turnaround times – Express 1 and Express 2, for example, have achieved an unheard-of-time of just 28 minutes – full load to empty to full load. Trucks and semis can be driven forward and turn 180° to drive back out – no reversing required!

And with a combination of advanced hull design and the world's leading engines and marine jets, operating costs (including maintenance) are minimised.

Incat's "production line"

Part of the company restructure mentioned above involved a detailed examination of Incat's work procedures. During construction the large ship moves through three stages of the shed on railway bogies until it reaches the final drydock position ready for launch. Incat set up various production facilities around the ship-building facility itself to ensure that the various components required were made on time and to the highest quality.

Up to six vessels can be constructed at the one time and they are more than likely to be different models (depending on orders), so it is essential that the shipbuilders receive the right components at the right time.

After the design is finalised by the Revolution Design team and the client's particular requirements, the **plate shop** sets about cutting the high-strength marine-grade aluminium alloy from which the ship is constructed.

Specialised suppliers in Australia, France and Switzerland supply the aluminium.

In **pre-fabrication**, these components are welded into larger modules (in fact, some smaller vessels are completely constructed here).

Then the focus is on the main assembly halls – it is here, in **stage one** of the assembly itself, where the larger components (fuel tanks, engine rooms, jet rooms and superstructures) are also transported. Naturally, many of these require installation/fitting at a relatively early stage of production.

Stage two of building sees the modules from pre-fabrication brought together and the "bits" start to resemble a

The BASTARD'S A GENIUS: the authorised biography of Robert Clifford

by Alistair Mant

"Bob Clifford is a hero of mine. I actually sought him out because I wanted to find out how on earth he had learned to do what he has done ... How did he do it? I believe he is a genius." – Dick Smith

The story of how Robert Clifford went from being a poor student to a global shipping entrepreneur reads more like adventure fiction than cold hard fact. But it is all true.

The tale contains the usual quota of disaster and triumph, spiced with a fascinating account of ingenuity and invention at work.

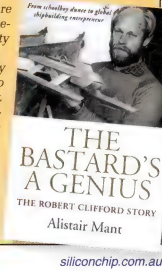
After all, if you go into business, you might as well experience a financial meltdown and a bank receivership. If you take up yachting, you might as well win the Sydney-Hobart race in a near photo-finish.

If you invent and then dominate a global fast-ferry market, you might as well win the Hales Trophy for the fastest Atlantic crossing, not once but three times.

But behind the swashbuckling adventure story lies a complex, affectionate and little-understood man of surprising sensitivity and creativity.

He is an all-action hero consumed by the need to conceive, shape and bring to fruition objects of great utility and beauty.

He is a man quite unlike the standard-issue 'businessman' and much more like those distinguished artists and scientists who are impelled by some inner voice to do the work they do.



The Bastard's a Genius
by Alistair Mant
– Allen & Unwin 9781741143

Vehicle (left) and pedestrian (right) access onto the *Volcano de Teno*, a 96m vessel operating in the Greek Islands. For ferry operators, minimum turnaround time is essential.

ship. Construction begins in the centre of the vessel, with controlled, rapid growth ensuing. As the ship "grows", quality assurance and marine survey authorities monitor every step.

Stage three sees engines, jets, thrusters and T foils installed and internal fitout, plumbing, wiring, hydraulics and myriad other ship's components and systems are fitted.

Also at this time, the ship is given her coats of paint and decoration, in accordance with the client's specifications.

Launching and delivery

Almost completed, it is ready for launching. Only at this stage is it given its new owner's name, logos etc – and once launched, such things as radio and radar antennas – too high to be installed inside the assembly hall – are fitted.

Builder's trials and sea trials are then conducted, ironing out any minor problems, before delivery is made. For smaller craft, this can be as deck cargo on a much larger vessel; for Incat's largest models, this may be made by sailing the vessel to the client – a perfect sea trial, if ever there was one!

The most recent (April 2017) Incat craft, the 109m Express 3, was delivered in this manner to Denmark, via the Panama Canal on May 23 last.

The Tasmanian Fast Ferry Museum, on Incat's site in Hobart. School excursions and other groups can book to visit this most interesting museum (phone 03 6271 1333).

Another Australian World-Beater: *Liferaft Systems Australia* Marine Evacuation System

One-person operation can evacuate 600 in less than 30m!

Our flying visit (literally!) to Incat Tasmania wouldn't have been complete without stopping in to their next-door neighbours (but independent company) Liferaft Systems Australia (LSA).

LSA have also earned a name for themselves around the world as the inventors and manufacturers of a completely new and different way of evacuating and rescuing those in peril from a doomed ship.

You've all seen the movies where the officers are shouting "women and children first" as they clamber into liferafts or lifeboats, which are then lowered into the water, sometimes not real successfully, by several crew members manning the winches. You just know it's not going to end nicely for at least some of them . . .

LSA, a privately-owned Australia company established in 1992, have developed a completely different method. Their Marine Evacuation System (MES) is more akin to the emergency evacuation slides you've seen (at least on TV) to get people away from a downed aircraft. LSA's system is much faster and much safer than the "old way".

The system developed by LSA comprises an inflatable evacuation slide, which leads directly into a large capacity inflatable liferaft, which can hold 50 or 100 people in a self-righting version with canopy or 128 people in an open, reversible version.

Both the slide and the raft are stored in a marine aluminium cradle, usually in a purpose-made "hatch" on the side of the vessel or on deck. Each is designed for rapid installation and rapid removal and can be actuated by one trained crew member. No power is required to operate it, there are no winches nor complicated hydraulics.

But when time is vital in evacuating passengers and crew, up to 600 people can be evacuated by each MES station in less than 30 minutes. Moreover, it doesn't discriminate on age, physical impairment, injuries or physical ability. The way the slide is designed means there is no risk of blockages while injuries (or further injuries) are virtually unknown.

The LSA MES is designed to suit (and is being used on) all types of vessels, including conventional passenger ferries, high speed craft, military vessels and even large private yachts – including, as you might imagine, all vessels made by Incat.

More information: LSA (03) 6273 9277; www.lsames.com SC

By
LEO SIMPSON

LED downlights and dimmers

In the past two years there has been a quiet revolution in the domestic lighting market. Incandescent and compact fluorescent lamps are rapidly disappearing, being supplanted by LED lamps of all sorts. But while LED lamps are great for low power consumption, they cannot be used with conventional leading-edge dimmers, which are ideally suited to incandescent lamps. This article surveys the domestic LED lamp scene and discusses the leading-edge, trailing-edge and universal dimmers.

Some years ago, incandescent lamps were largely banned from the Australian and New Zealand markets, with a variety of incentive schemes sponsored by governments to promote the use of more efficient compact fluorescent lamps (CFLs).

While this may have been well-intentioned, CFLs often failed to live up to their promise of long life and for a number of reasons, they proved to be a less than satisfactory replacement for incandescent lamps in many applications.

Now CFLs are rapidly being displaced from the market and LED lamps are taking their place. Nowhere is this more apparent than in newly constructed homes and home units where the overwhelming lighting choice is flush-mounted ceiling LED downlights.

But there is also an ever-expanding range of direct substitutes for incandescent lamps.

In fact, apart from the occasional LED accent light or a rail light, or in situations where their use is precluded (eg, bathroom heat lamps) LED downlights are now the universal choice for domestic lighting in new dwellings. This will be confirmed if you take a walk through any newly constructed home or home unit. Or have a look at any new project home – downlights are used in just about every room.

These "Clipsal" trailing edge dimmers are specifically intended for use with mains-powered LED lamps (up to 400W).

Apart from the whims of fashion, there are two main reasons for this trend. First, all new dwellings in Australia must meet the Building Code of Australia for energy efficiency, and in New South Wales, the BASIX energy standard.

Both standards set out how much lighting, based on power consumption, can used per unit area of the dwelling. This effectively rules out the use of incandescent, 240VAC halogen and particularly 12V halogen lamps, because they are power gobblers.

The second reason is that virtually all new homes and home units in Australia are built with a minimum ceiling height of 2.4 metres. This means that headroom below hanging light fittings can be insufficient for tall people. Who likes to be banged on the head by a low-flying pendant light fitting?

Conventional light fittings also often have poor light distribution and apart

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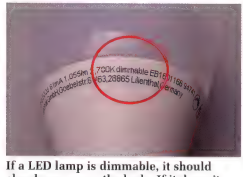
We made this jig to show the differences in light colour from various types of lamps (unfortunately printing processes tend to mask the differences somewhat). On the left is a "cool white" (4000K) 15W CFL; second is a "warm white" (2500K) 15W CFL; third is a "warm white" (2700K) 60W incandescent (shh!) while on the right is a "cool white" (labelled 2700K!) 13W LED.

from that, they are dust-catchers which can make small rooms seem even smaller.

So flush-mounted ceiling downlights are a neat solution and they provide a bonus in giving lots of light for relatively little power; typically 10 to 14W. A further benefit is that when they are off, they virtually disappear into a white-painted ceiling.

We should also note that there are LED equivalents to the familiar MR16 12V halogen downlights but these are less widely used and they are generally not as bright. The LED downlights we are referring to require a 92mm cut-out in the ceiling, vs 75mm for the MR16s.



If a LED lamp is dimmable, it should clearly say so on the body. If it doesn't say so, it isn't! And then it's only with a trailing edge dimmer.

LED disadvantages

So what are the drawbacks? There are several but the main one is that most LED downlights are not dimmable – and those that are will not work with conventional "leading-edge" dimmers which are so effective with incandescent lighting. So why dim them at all?

The over-riding advantage of LED downlights is that they are bright, particularly those that are rated Cool White (typically 5000K) or Natural White (4000K); Warm White (typically 2700K). Warm white LED lamps are intended to imitate the lighting given by incandescent lamps and as a consequence, they are considerably less bright.

But the high brightness of Cool White or Natural White LEDs can be too bright and harsh for many rooms, particularly in bedrooms but also in lounge and dining rooms where full brightness may not be required for most of the time.

In those situations, dimmers become highly desirable. But most LED downlights, in fact most LED lamps, are not dimmable. Furthermore, all LED lamps are marked on their packaging as to whether they are dimmable or non-dimmable. More usefully, some LED downlights are labelled as "trailing edge" dimmable. If you cannot find any information on the packaging, you can assume that any LED lamp is not dimmable.

The reason that most LED lamps are not dimmable is that they employ a switchmode power supply which will work over a very wide range of AC mains voltage. Most will work at voltages between 250VAC and around 80VAC, with very little change in brilliance.

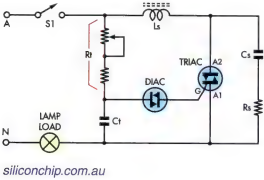
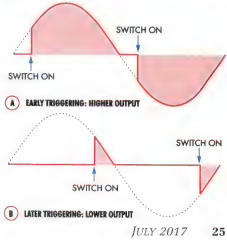
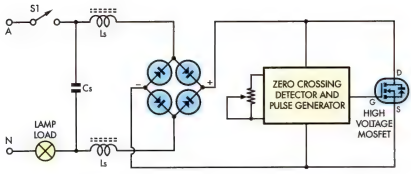


Fig.1 (left) shows the circuit of a typical "leading edge", triac-based light dimmer. Fig.2 (right) shows the waveform across the lamp load – when triggered early, the lamp is at its brightest, while it gets progressively dimmed as the trigger point (set by variable resistance R1) is later in the half-cycle.





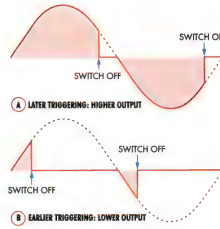


Fig.3 (above): a "universal" dimmer can be set to leading edge or trailing edge. A high voltage Mosfet is used to switch the load.
Fig.4 (right): the waveform across the lamp is essentially the opposite of Fig.2 – in this case it's for a "trailing edge" dimmer which turns the power off at a certain point in the cycle; the later it does so, the brighter the lamp.

If you do try them out with a conventional light dimmer, they will not dim but will inevitably flicker uncontrollably.

Dimmable LED lamps have a slightly more complicated switchmode power supply which allows their brilliance to vary in proportion to the mains supply voltage, although typically, their brilliance cannot be varied over the same wide range as that for incandescent lamps.

Sadly, while a LED lamp may be labelled as being dimmable, they will not work if you try them with a standard dimmer that may have been installed in your home for a number of years. That is because it will be a Triac-based "leading edge" dimmer.

What you need for LED lamps is a "trailing edge" or "universal" dimmer. But even if you have a trailing edge dimmer installed, it may not work satisfactorily with your particular "dimmable" LED lamp.

Before we discuss why a dimmer may or may not work with a LED lamp, let us define and describe "leading edge" and "trailing edge" dimmers. As already noted, leading edge dimmers are based on Triacs and the general layout of a Triac dimmer is shown in Fig.1.

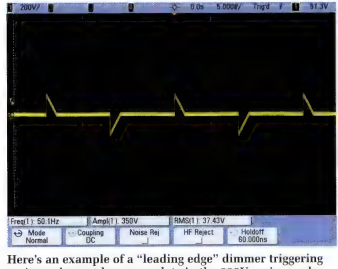
A Triac is a a four-layer bi-directional semiconductor device which is non-conducting until a small trigger pulse is fed to its gate electrode. It then switches to a low resistance state, allowing current to be fed to the load until the voltage across it (the Triac) drops to zero or reverses in polarity.

In more detail, as well as the Triac as the power switching element, there is an RC network (R_T and C_T) and a Diac (another four-layer semiconductor device) which provides the phase-delayed triggering pulse to the gate of the Triac (see Fig.1).

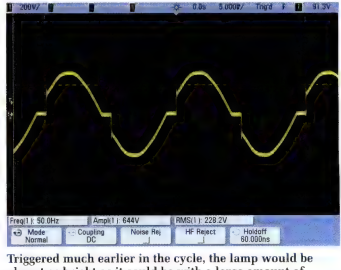
The triggering network is effectively a pulse generator synchronised to the mains voltage waveform. So at the start of each half-cycle, the Triac will be off and the capacitor connected to one side of the Diac will charge, at a rate determined by R_T, to between 30 and 40V where it reaches the "breakover" voltage of the Diac. The Diac then dumps the capacitor's charge into the gate of the Triac, turning it on so it can pass current to the load.

The inductor L_S, capacitor C_S and resistor R_S are for interference suppression and voltage "snubbing" to reduce transient voltages when the Triac turns off at the end of each half-cycle.

The method by which a Triac controls the power level in an AC circuit is referred to as "phase control". Consider that the mains voltage is a 230VAC sinewave; the voltage varies sinusoidally between +325V and -325V at 50Hz (or 60Hz in the Americas and some other countries).



Here's an example of a "leading edge" dimmer triggering an incandescent lamp very late in the 230V mains cycle. Only a small amount of power is delivered to the lamp.



Triggered much earlier in the cycle, the lamp would be almost as bright as it could be with a large amount of power delivered.

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Similarly (to the earlier photo), at left is a 2.5W LED "COB" lamp (bordering on useless!); next is a "cool white" 16W LED; a decorative "warm white" 75W incandescent and finally the same 13W "warm white" (2700K[?]) LED as before. Even though that 2700K is on the label, we don't believe it. The incandescent lamp to its left would be much closer to 2700K.

The power fed to the lamp load by the Triac dimmer circuit is varied by the timing of the gate trigger pulse with respect to the sinusoidal voltage waveform. If the trigger pulse is early in each half-cycle of the waveform, the power level will be high and the lamp will be bright.

Conversely, if the trigger pulse is late in each half-cycle of the waveform, the power level will be low and the lamp will be dimmed. The corresponding circuit waveforms are shown in Fig.2 and the scope screens below.

These Triac circuits are also referred to as "phase-controlled" dimmers (sometimes also referred to as "phase-cut" dimmers). So far so good but what is the basis for the term "leading edge"?

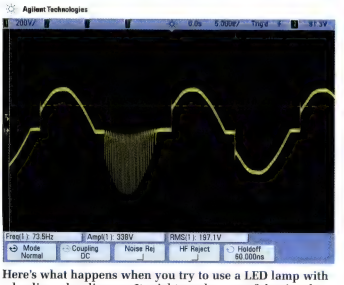
In fact, leading edge refers to the "leading edge" of a pulse where the voltage rises from zero to maximum (either positive or negative).

By extension, the end of the pulse is referred to as "falling" or "trailing edge". So the voltage waveform fed to the lamp load by the Triac rises from zero to the instantaneous value of the sinusoidal voltage at the time of the trigger pulse to the gate – hence, by definition, that is a "leading edge".

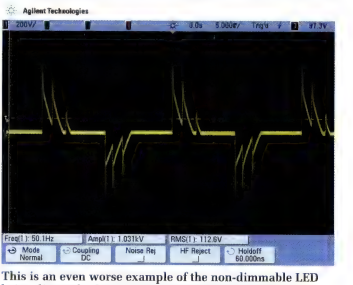
Trailing-edge dimmers

OK. So now let's look at a typical trailing edge dimmer. Instead of being based on a Triac, these are based on one or two Mosfets or IGBTs (Insulated Gate Bipolar Transistor) depending on the particular circuit.

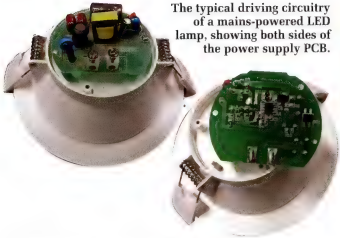
A typical single Mosfet trailing edge dimmer is fed by a



Here's what happens when you try to use a LED lamp with a leading-edge dimmer. It might work some of the time but is more likely to not work.



This is an even worse example of the non-dimmable LED being dimmed. The LED was noticeably flickering, as you can see by this very confused waveform.



The typical driving circuitry of a mains-powered LED lamp, showing both sides of the power supply PCB.

These flush-mounting 240V AC LED downlights from Altronics are available in 6 & 10W dimmable and 14 & 25W non-dimmable (the 25W are *very* bright!) in both cool white and natural white. Their rated life is 25,000 hours – *much* better than halogen bulbs!

bridge rectifier from the 230VAC mains supply, arranged so that the Mosfet switching element is turned on at the beginning of each mains half-cycle and then turned off later in the half-cycle. A general form of this circuit is shown in Fig.3.

The waveforms for the trailing-edge circuit are shown in Fig.4 and they are effectively the reverse of those for the leading-edge waveforms shown in Fig.2. In this case, for high power to be fed to the load, the Mosfet is turned on at the start of each mains half-cycle and is turned off late.

Note the trailing-edge cut-off as the Mosfet switches off. For low power operation, the Mosfet turns off much earlier in each half-cycle.

So why is the trailing-edge dimmer preferred for LED lamps? There are two main reasons.

The first is that typical mains voltage-rated LED lamps use a small switchmode current driver, comprising a bridge rectifier feeding a capacitor, which provides a supply voltage of around 325V DC to feed the switchmode current driver; typically using a small high voltage Mosfet.

These bridge rectifier capacitor input power supplies draw a very high current at the switching point on each half-cycle when feed by a leading-edge dimmer.

This can play havoc with the operation of the dimmer as well as the LED current driver itself.

However, when the same LED lamp circuit is fed with the more benign voltage waveform from a trailing-edge dimmer, those nasty current pulses into the capacitor input power supply are much more subdued.

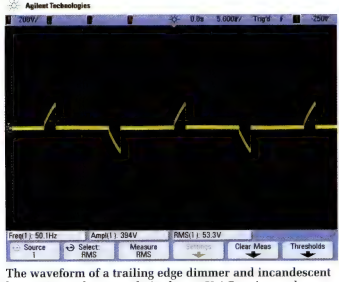
However, there is another reason why leading-edge dimmers and typical LED lamps are not compatible and this has to do with the "holding current" specification for a Triac.

For typical Triacs, this current is around 50mA. This is the current that needs to pass through a Triac for it to remaining a conducting state. If the current falls below the holding value, the Triac will switch off even though the total voltage across it and the accompanying lamp load might still be quite high.

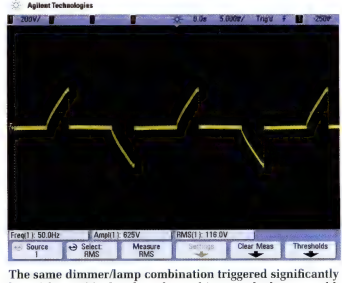
This is why a typical Triac dimmer has a minimum lamp load of 40W; any lower and the lamp will tend to flicker, regardless of the brightness setting. However, a LED lamp may only be rated at 10 to 15W (or less) – far below the minimum load for a Triac (leading-edge) dimmer.

Universal dimmers

Just to complicate the scene, there are "universal" dimmers which will provide a choice of leading-edge and trailing-edge operation. Hence, these can used in leading-edge mode to control incandescent and halogen lamps,



The waveform of a trailing edge dimmer and incandescent lamp triggered very early in the 230V AC mains cycle. There would be very little light produced by the lamp.



The same dimmer/lamp combination triggered significantly later (about 1/3) of each cycle. In this case, the lamp would be glowing but not particularly brightly.

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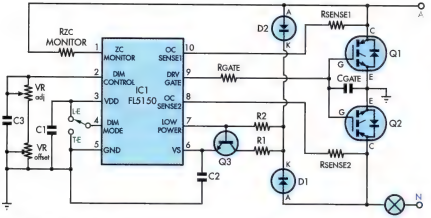


Fig.5: taken from the Fairchild data sheet, the FL5150 dimmer which can be set for leading edge or trailing edge.

or in trailing-edge edge mode, to control dimmable LED lamps and dimmable compact fluorescent lamps (CFLs).

These typically use two high voltage Mosfets or IGBTs controlled by a special driver such as the Fairchild FL5150 or the ST STEVAL-1LD005V1.

Fig.5 shows the Fairchild FL5150 in a 230VAC circuit using two high voltage IGBTs; in this case set up for leading-edge operation (selected by the DIM mode pin).

Note that regardless of whether you elect to use a trailing-edge or universal dimmer with a dimmable LED lamp, there is no guarantee that they will work happily together.

Or you may get a situation where a dimmer will work happily with just a few LED lamps connected in parallel in a small room but may misbehave with a larger array of LED downlights.

Some licensed electricians will only use a particular brand and model of universal dimmer because they may have found it to be reliable in the past.

However, there is nothing to stop you from bench-testing a particular light dimmer and some LED lights to see if they are OK, before they are installed by a licensed electrician.

Waveforms and performance

We have run a series of tests with leading-edge and trailing-edge dimmers and produced a series of waveforms, shown below.

Both the leading-edge and trailing-edge dimmers were made by Deta, a low cost brand sold in Bunnings hardware stores.

The Deta 6031 trailing-edge dimmer worked satisfactorily with the dimm-able LED downlights discussed in this article but the only way to be sure is to do a bench test set up.

Rather than comment on the waveforms in detail, we'll let the waveforms and the captions tell the story.

However, there are significant differences in performance between leading-edge, trailing-edge and universal dimmers. Apart from the fact that leading-edge edge dimmers simply won't work with LED lamps, they are better at driving incandescent and halogen lamps than the trailing-edge or universal types.

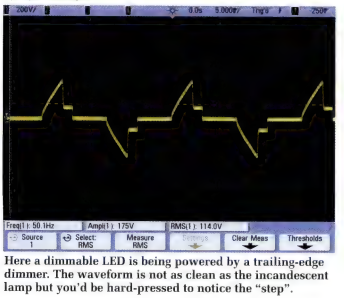
With an incandescent lamp, the maximum brightness is slightly higher (due to less conduction losses) and the minimum brightness is considerably lower, due to the fact that the minimum conduction angle in each half-cycle is much smaller than can be achieved with a trailing-edge or universal dimmer circuit (even when in leading-edge mode).

On the other hand, a trailing-edge (or universal) dimmer does have the advantage that it gives a soft turn-on rather than the instant snap-on effect with a Triac dimmer. A trailing-edge dimmer always gives a slight delay between switching on and the lamp actually lighting up.

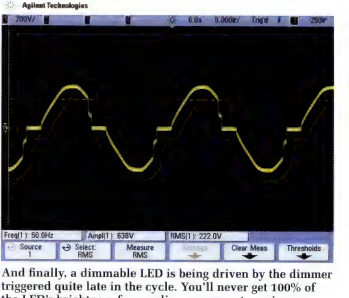
So if your Triac leading-edge dimmer had failed and you have yet to replace it, it is worthwhile to replace it with a trailing-edge dimmer.

This will provide the advantage of soft start which may also avoid the sudden failures of incandescent lamps at switch-on, together with the accompanying failure of the dimmer itself. This failure scenario is most common with lamp fittings where the lamp does not hang down but is upright.

The installation instructions that come with some leading-edge dimmers warn about this hazard.



Here a dimmable LED is being powered by a trailing-edge dimmer. The waveform is not as clean as the incandescent lamp but you'd be hard-pressed to notice the "step".



And finally, a dimmable LED is being driven by the dimmer triggered quite late in the cycle. You'll never get 100% of the LED's brightness from a dimmer even at maximum.

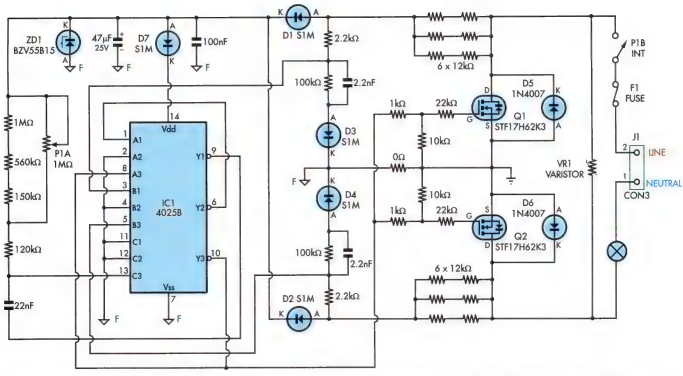


Fig.6: by contrast, this trailing edge dimmer uses two STF17N62K3 620V Mosfets and two diodes across the AC supply and in series with the lamp load. Interestingly, no microcontroller is used, with the switching being controlled by a CD4025BE CMOS logic gate device. It can handle lamp loads up to 300W on a 230VAC supply.

But if you like the ability of a leading-edge dimmer to give very low brightness setting with incandescent lamps, or if you need to drive a bigger lamp load, then stick with those. Typically, trailing-edge dimmers are limited to a maximum of around 300-400W.

On the other hand, if you want to provide for the day when you eventually change to LED lighting as incandescent lamps become too costly or hard to obtain, go for the trailing-edge dimmer.

Variable colour LED lights

Having discussed cool white and warm white LED lamps, we should note that there is at least one interesting variant: a downlight which can vary its colour temperature from cool white to warm white in response to varying input voltage.

Made by Opal Lighting (**www.opallighting.com.au**), they employ a special COB (chip on board) LED assembly from Sharp Corporation, called the Tiger Zenigata tuneable white COB. This COB has alternating LED stripes with cool and warm phosphor coating that ranges from 3000k down to 2000K, which most closely replicates the colour range of an incandescent lamp when dimmed by a leading-edge (Triac) dimmer.

Indeed, it must be used with a leading-edge dimmer or a universal dimmer that is set to leading-edge mode. We have a couple of pictures at the start of this article (page 24) to demonstrate its range.

We should also mention that colour sequenced LED pool

The all-in-one, mains-operated Phillips SmartBright LED batten photographed with the end cap removed (not an easy job!) There is no separate LED tube in this fixture; you can see the row of SMD LEDs disappearing into the distance. The bottom of the fixture is polycarbonate, the top (semi-circular) section is an integral diffuser.

This LED downlight is the popular 12W/220-240V AC cool white model and, as is marked, is trailing-edge dimmable. Light output is an impressive 900 lumens. They are designed to replacee the MR-16 12V halogen downlights used in millions of homes and offices – but no 12V transformer is needed. They also need a larger (92mm) ceiling cutout.

At left is a 15W 240V decorative "candle" MES globe, with its 4W warm white LED globe equivalent alongside. Below, the same two lamps are fitted in the one "wall sconce". Their brightness and colour are not all that different.

lights are available which can typically provide a choice of three colours, white, blue and green, cycled each time the lamp is turned on.

LED fluorescent battens

In the September 2010 issue, we featured an article on then relatively new (and expensive) LED fluorescent tubes for use in standard 36W T8 fluorescent battens. (See **www.siliconchip.com.au/Article/277**).

These are now available much more cheaply but you can now also purchase LED battens such as the Philips SmartBright LED Batten (see **https://reductionrevolution.com.au/products/philips-smartbright-led-batten**).

These do not have a separate LED tube but use a 1.2m-long PCB with a row of SMD white LEDs under a white diffuser. A switchmode mains power supply is incorporated in the polycarbonate housing of the batten which will operate down to about 80VAC with very little change in brightness.

They are rated cool white (4000K), consume 21W and are not dimmable.

Conclusion

As this article shows, there is now an enormous range of LED lamps to replace virtually every incandescent and fluorescent lamp used in homes and offices.

About the only lamp application where a LED replacement could not be used is in conventional electric ovens, microwave ovens and lamps incorporated into kitchen exhaust hoods.

It also may not be advisable to replace the incandescent lamp used in combination bathroom exhaust fan/heat lamps as the housing can become quite hot.

One final point: you may have noticed that we refer to both LED lamps and incandescent lamps as "240V" in this feature when the mains supply in Australia is (nominally) 230V AC. The reason is that most lamps are labelled 240V AC, (some are labelled "250V AC"). Indeed, many LED lamps are labelled "220-240" or even "220-250" V AC. SC

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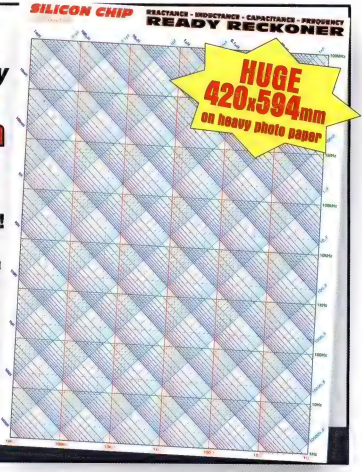


Give the guy behind you more time to pull up!

by John Clarke

RapidBrake

EMERGENCY STOP signalling for virtually any vehicle

Every time you need to brake heavily to avoid an obstruction there is a risk that a following vehicle will crash into you. But you can significantly reduce the risk of that happening with the RapidBrake. Normal brake lights won't necessarily give other drivers sufficient warning but this easy-to-build unit will flash your hazard lights during heavy braking to give following drivers a more dramatic warning.

You may have noticed that some modern vehicles, when braking heavily, will flash their brake or hazard lights at a fast rate.

It's called "vehicle emergency stop signalling" and serves as a visual warning for following vehicles where they may need to quickly slow down to avoid running into the car in front.

Does your car have emergency stop signalling? Probably not. But you can add it with the RapidBrake and reduce the risk of a nose-to-tail collision.

Remember, your brake lights indicate to others that you are braking but they don't indicate how hard you are braking – so they won't grab other drivers' attention in the way that RapidBrake will.

Around 23% of all vehicle collisions are nose-to-tail collisions. These collisions are more likely to happen during rapid braking where the driver of the vehicle behind is too close and/or unaware of how hard the vehicle is braking.

Flashing the brake or hazard lamps clearly expresses the sense of urgency to the applied braking and may snap the driver behind out of their trance and get them to ap-

Features

- Detects hard braking and warns other drivers by flashing the brake or hazard lamps
- Complies with Australian Design Rules 13/00 and 31/02 vehicle standards
- Adjustable deceleration thresholds
- Test points and diagnostic output provided for calibration
- Onboard/off-board LED to indicate when the unit is triggered
- Uses a 3-axis accelerometer
- Compensation for up-hill and down-hill road conditions
- Can be mounted in two different orientations
- Suitable for cars and trucks but not motorcycles

ply their brakes with the same vigour.

RapidBrake details

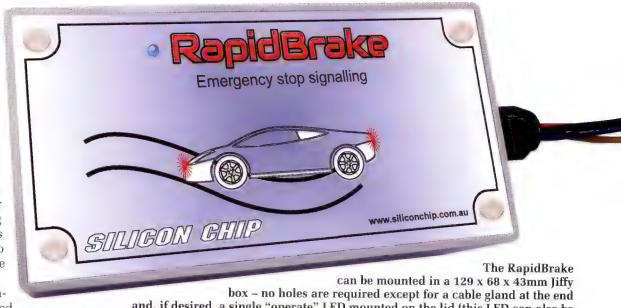
RapidBrake is presented as a PCB module that is housed in a small plastic case. The PCB includes an accelerometer module, processing circuitry and relays for connecting to the hazard or brake lamps.

RapidBrake is intended to be installed under the dashboard, with connecting wires made to the ignition switch and chassis for power and to the brake switch or hazard lamps.

Under normal braking, the brake lights will light normally and the hazard lights will not flash unless intentionally switched on using the normally dash-mounted switch.

RapidBrake only starts to rapidly flash the brake lights or the hazard lights when it detects heavy braking.

Whether RapidBrake flashes the brake lights or the hazard lights is your choice and is determined by how you wire it into the vehicle.



The RapidBrake can be mounted in a 129 x 68 x 43mm Jiffy box – no holes are required except for a cable gland at the end and, if desired, a single "operate" LED mounted on the lid (this LED can also be externally mounted). Power is supplied via the vehicle's switched "ignition" line.

Australian Design Rules

RapidBrake follows the Australian Design Rules (ADR) for vehicle emergency stop signalling. These standards set the flash rate and how the rapid braking rate is detected.

The permissible flashing rate is defined by "Vehicle Standard (Australian Design Rule 13/00 – Installation of Lighting and Light Signalling Devices on other than L-Group Vehicles) 2005".

Section 6.23.7.1. of ADR 13/00 states that "*all the lamps of the emergency stop signal shall flash in phase at a frequency of 4.0±1.0Hz.*" However, section 6.23.7.1.1. states that "*if any of the lamps of the emergency stop signal to the rear of the vehicle are filament types, the frequency shall be 4.0+0.0/-1.0Hz.*"

RapidBrake uses a 3.85Hz flash rate and that's just under the 4Hz maximum for filament lamps. We chose this frequency to suit both LED and filament lamps.

There are options for how rapid braking is detected. "ADR 31/02 – Brake Systems for Passenger Cars". Section 5.2.23.1. states that "*emergency stop signalling shall be activated by the application of the service braking system at a deceleration of or above 6m/s² and de-activated at the latest when the deceleration has fallen below 2.5m/s².*"

Alternatively, section 5.2.23.2. of ADR 13/00 says "*the emergency stop signalling may also be activated when brakes are applied at a speed above 50km/h and the anti-lock braking system (ABS) is fully cycling. It shall be deactivated when the ABS is no longer fully cycling.*"

We opted not to use this alternative method as it would preclude RapidBrake from being used in a vehicle that does not have ABS. This method also requires access to digital signals that may not be available in an older vehicle.

Accelerometer

RapidBrake activates signalling based on detecting deceleration rates as detailed in the first option, by using a 3-axis accelerometer.

This means that RapidBrake can be used in any vehicle.

An accelerometer will measure the acceleration and deceleration of the vehicle together with the force of gravity.

You can read more details about

QuickBrake

We published a related project, the Quickbrake, in January 2016. This detects if you rapidly lift your foot from the accelerator pedal and activates the brake lights well before you have time to place your foot on the brake. Quickbrake can typically provide an extra half-second of brake lights indication for the driver of the vehicle following you to take appropriate action. See: **www.siliconchip.com.au/Article/9772**

You could incorporate both QuickBrake and RapidBrake into the same vehicle for maximum safety. Alternatively, you can just use RapidBrake on its own if QuickBrake is not suitable for your vehicle or you prefer not to have Quickbrake.

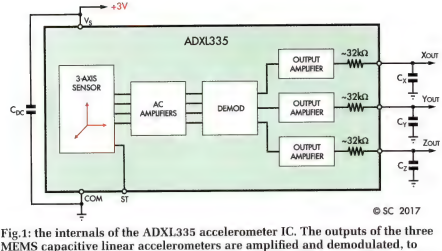


Fig.1: the internals of the ADXL335 accelerometer IC. The outputs of the three MEMS capacitive linear accelerometers are amplified and demodulated, to remove the capacitor switching frequency. The resulting DC is then further amplified and fed to the output pins via nominal 32kΩ internal impedances, so that external capacitors can be used to determine the bandwidth.

this in the panel opposite titled "Accelerometers".

The accelerometer we are using is a 3-axis module designed for use with Arduino (but not limited to such). It is available from Jaycar with catalog code XC4478. The module incorporates a 3V regulator and an Analog Devices ADXL335 3-axis accelerometer IC. 100nF output capacitors (C_X, C_Y and C_Z) filter the separate analog outputs for the X, Y and Z axes.

Fig.1 shows the block diagram of the ADXL335 accelerometer IC. The accelerometer outputs indicate the separate components of deceleration or acceleration along the X, Y and Z axes. The readings are a result of gravity and acceleration due to changes in velocity.

We only use two outputs from the accelerometer module for the RapidBrake; the Z output and either the X or Y-axis output. You get to choose which output (X or Y) is used and that depends upon the orientation of the RapidBrake unit when installed in your vehicle. The Z-axis is always used and is oriented in the up/down direction, sensing gravity and vertical acceleration.

The X or Y-axis output is selected to be the one that's oriented fore and aft inside the vehicle. Fig.2 shows the orientation of the accelerometer within a vehicle with either the X or Y outputs.

The following description assumes the X output is used but it works basically the same way if the Y output is used.

The accelerometer X-axis is arranged to be parallel with the floor of the vehicle. On a flat road, this axis is horizontal and the accelerometer's X output sits at a half supply voltage, indicating no acceleration/force.

With the XC4478 module oriented inside the vehicle as shown, the output increases above this half supply with deceleration (slowing down) and decreases below the half supply rail under acceleration (increasing speed).

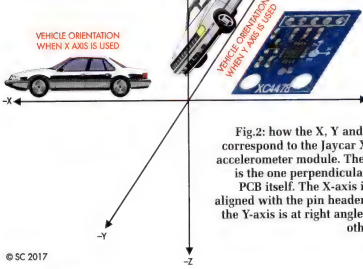


Fig.2: how the X, Y and Z axes correspond to the Jaycar XC4478 accelerometer module. The Z-axis is the one perpendicular to the PCB itself. The X-axis is the is aligned with the pin header, while the Y-axis is at right angles to the other two.

Detecting the deceleration rate

Detecting deceleration seems like it should be should be simple: just measure the X output voltage that is produced when braking and at a deceleration of 6m/s^2, activate the emergency stop signalling.

Then when deceleration has fallen below 2.5m/s^2, stop the emergency stop signalling.

That would be valid if the vehicle is travelling along a horizontal road, but with undulating terrain, it is not quite as easy.

When the vehicle starts to go up or down a hill at a constant speed, the X output changes (even with no acceleration or deceleration). That is because the X-axis is no longer horizontal and so there is a gravity component incorporated into the X-axis reading.

The X output will increase when pointed down hill and decrease when pointed up hill. That will a major effect on the X output voltage level when the vehicle is accelerating or decelerating up hill or down hill.

The amount that the X output changes with angle is quite significant. If the vehicle is facing down a 37.71° hill, the 6m/s^2 threshold will be reached without any braking.

That would be an impossibly steep hill; for example, Sydney's steepest hill, Attunga Street in Double Bay, has a slope of 14°.

But it does indicate the magnitude of the problem; coasting down Attunga Street would still give an X output equivalent to a deceleration of 2.5m/s^2.

So in that case, it would only require an extra 3.5m/s^2 of braking deceleration will start the emergency stop signalling.

Even if the vehicle comes to a halt on that hill, the lower 2.5m/s^2 threshold will not be reached and the emergency

Accelerometers

An accelerometer is a device that measures static and dynamic acceleration forces. Static forces are generally due to gravity while dynamic forces are due to movement.

The term "accelerometer" is arguably a misnomer since it need not be accelerating or even moving to make a non-zero measurement.

An accelerometer actually measures force but is calibrated in such a way that its own mass is eliminated from the reading, hence the measurements are in units of acceleration (m/s^2).

This is termed "proper acceleration" and is defined as the "acceleration relative to a free-fall, or inertial, observer who is momentarily at rest relative to the object being measured"; see **https://en.wikipedia.org/wiki/Proper_acceleration**

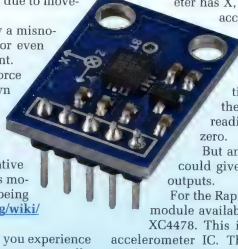
Consider that standing on the ground, you experience the downward force of gravity but you are not actually accelerating because the ground is pushing up on you with the exact same force, cancelling it out. But an accelerometer will still measure this gravitational force.

Accelerometer output is normally calibrated to show acceleration forces in "g" units where 1g is the gravitational force experienced by an object near the Earth's surface and equates to 9.81m/s^2.

Accelerometer readings can be from one of several sources. One is due to the change in speed along a straight line. So an accelerometer can, for example, measure a vehicle's acceleration as it moves off from a standing start. It can also measure deceleration of a vehicle under braking. Note that we use the word deceleration although this is just acceleration in the opposite direction.

An object moving at a constant speed but changing direction also experiences a sideways cornering force and an accelerometer can measure this too. The third measurement from an accelerometer is that due to gravity, as described above.

Accelerometer measurement is along one axis only so if there is acceleration at right angles to the axis, then there will be no measurement. Many accelerometers include three separate measuring elements, so that acceleration in any direction can be measured. A 3-axis accelerometer has X, Y and Z axis outputs. The actual acceleration vector can be determined by making a vector sum of the acceleration measurements along each individual axis.



So if, for example, the acceleration is along the X axis, then only the X output will show a change in reading. The Y and Z outputs will read zero.

But an acceleration within the Z-plane could give a reading on both the X and Y outputs.

For the RapidBrake, we use an accelerometer module available from Jaycar with catalog code XC4478. This incorporates an ADXL335 3-axis accelerometer IC. This is a MEMS (Micro-Electro-Mechanical Systems) device. It contains very small electromechanical components to make up the accelerometer sensors.

A MEMS accelerometer can be imagined as a small mass attached to a spring. Added circuitry detects movement of the mass that either compresses or expands the spring, depending on the force of acceleration. The electromechanical components comprise a polysilicon sensor suspended on polysilicon springs for each of the three X, Y and Z planes.

When the accelerometer sensor moves, the change in the mass position alters sensor capacitance and so provides a measurement of acceleration. For a more detailed description see **www.instrumentationtoday.com/mems-accelerometer/2011/08/**

We also described the operation of an accelerometer in our August 2011 article on the Digital Spirit Level project; see **www.siliconchip.com.au/Article/1122**

Fig.2 (opposite) shows the three axis orientations for the XC4478 module containing the ADXL335 accelerometer IC. Acceleration in the positive axis direction or deceleration in the negative axis direction produces an increasing output for that axis.

stop signalling will not cease. These would both result in the violation of ADR 31/02.

The way around this problem is to also utilise the reading from the Z-axis.

On a horizontal roadway, the Z-axis output will be reading the full effect due to gravity. As the angle moves off from horizontal, the Z output reading reduces in value.

This reduction follows a cosine curve where the output is at its maximum (measuring the full acceleration due to gravity) for a 0° slope and the output is zero (ie, at half supply) for a 90° slope.

The output is reduced by 3% for a 14° slope, ie, (1 – cos(14°)) x 100.

Similarly, for the X output, the increase or decrease with slope follows a sine curve.

The change in output is zero for a 0° slope and sees an increase of 24% for a 14° slope, ie, sin(14°) x 100. It is measuring the full acceleration due to gravity for a 90° slope (also known as a "cliff").

Although the change in the Z output for normal road slopes is small, by amplifying the Z output and doing some calculations, we can use the Z output to compensate for changes in the X output that are due to slope.

So effectively, we can compute a compensated X output value that does not change with slope over a range of slope angles.

This compensation does not affect the readings caused due to the vehicle's own acceleration or deceleration. That's because the acceleration and deceleration occurs along the X-axis only.

The Z-axis is perpendicular to the acceleration and deceleration along the X-axis and so it is not affected.

We store the "quiescent" accelerometer X and Y output values, from when the accelerometer is in a horizontal position, in the microcontroller's non-volatile memory (EEPROM).

These values are set during calibration. Whether the vehicle is going up or down hill is determined by comparing the X reading with the stored horizontal quiescent X value. If the X reading is greater in value compared to the quiescent, then the vehicle is facing down hill. If the X reading is less than the quiescent then the vehicle is facing uphill.

The Z reading due to gravity will always be less than the quiescent horizontal Z value if the unit is not perfectly level. Since we know whether the vehicle is going up or down hill, the compensated reading is produced by reducing the X axis reading if the vehicle is going downhill or increasing it when going uphill.

The amount of compensation applied is non-linear, in accordance with the fact that the Z output changes following a cosine curve and the X output following a sine curve with respect to the slope angle. In practice, a lookup table in the software is used to calculate the required compensation amount, with an adjustment included for compensation gain. The result is an acceleration/deceleration value which does not change depending on slope angle.

Gain compensation is determined by the calibration procedure. This is required to account for the fact that the X output voltage at 1g may not be exactly the same as the Z output voltage at 1g. This is due to manufacturer tolerances in the accelerometer as well as differences in gain in the op amp circuits.

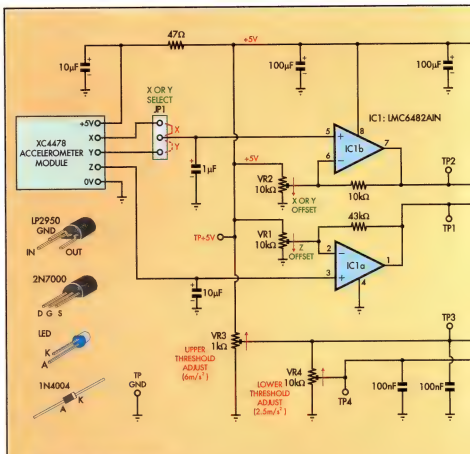
It is the compensated value that's compared against the upper and lower deceleration thresholds for braking, to determine whether or not to activate the emergency flashers. By the way, the fact that the X output will be using a wider part of its output range due to the effect of gravity on the readings does not affect accuracy.

Linearity of the sensor is within 0.3% from 0 to 3g (3 x 9.81m/s^2 or 29.4m/s^2) which more than covers the range the sensor will experience during driving.

Note that we don't use the Y output to compensate for any changes in the Z-axis gravity reading output due to road camber.

That's because the accelerometer in the Y axis cannot distinguish between gravitational changes due to a slope and acceleration caused by cornering. While there is very little change in readings due to camber (because camber is rarely more than a few degrees), the cornering acceleration can be much higher.

So using the Y output for compensation of readings could result in severe errors.



Circuit details

The full circuit for the RapidBrake is shown in Fig.3. The circuit comprises the accelerometer module, dual operational amplifier (IC1), microcontroller (IC2) plus a regulator, relays and associated components.

The XC4478 accelerometer module is powered from a 5V supply via a series 47Ω resistor and decoupled using a 10µF capacitor, forming a low-pass filter which rejects supply noise. The module contains its own 3.3V low-dropout regulator.

The Z output is filtered using a 10µF capacitor that effectively gives the output a one-second response to variations in acceleration, in combination with the 32kΩ resistance built into each of the accelerometer IC's outputs.

Amplifier IC1a provides gain for the module's Z-axis output signal, with VR1 allowing its DC offset voltage to be adjusted. Gain is typically around 9 times and is dependent upon the 43kΩ feedback resistor and the setting of VR1.

JP1 is used to select which of the X or Y output is fed to the microcontroller from the accelerometer module. The selected output is output is filtered using a 1µF capacitor that effectively gives a 100ms response to variations in acceleration.

Amplifier IC1b provides gain for this signal with VR2 setting the DC offset and adjusting the gain all at once. Gain is typically around 3 times and is dependent upon the 10kΩ resistor value and the VR2 setting.

The acceleration signals are monitored at the analog inputs AN2 and AN3 of microcontroller IC2. IC2's firmware uses its internal analog-to-digital converter (ADC) to convert

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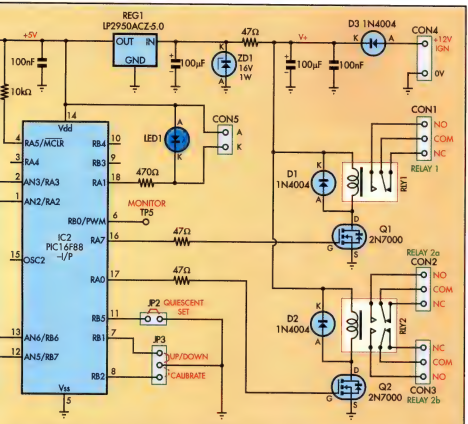

Fig.3: complete circuit for the RapidBrake. Two of the analog outputs of the accelerometer module are fed to dual op amp IC1a and IC1b which amplifies them and those amplified signals are then fed to two analog inputs of microcontroller IC2. Trimpots VR3 and VR4 feed two other analog inputs, to set the upper and lower deceleration trigger thresholds respectively. If triggered, output pins RA0, RA1 and RA7 combine to flash LED1, switch on RLY1 and switch RLY2 on and off at just under 4Hz.

the voltages at these inputs to digital values.

After compensating the X or Y signal at the AN3 input using the Z signal at the AN2 input, the resulting value is compared against the settings from VR3 and VR4.

VR4 sets the upper 6m/s^2 threshold for braking, while VR4 sets the 2.5m/s^2 lower braking threshold.

VR3's wiper connects to the AN6 analog input of IC2, while VR4's wiper connects to the AN5 input. The voltages at these inputs are converted to digital values in a similar way as for the AN2 and AN3 inputs.

Note that VR4 connects between the wiper of VR3 and the 0V supply rail. This means the wiper of VR4 can only range between 0V and up to the wiper voltage set by VR3.

This is done so it is impossible to have the lower threshold set by VR4 any higher in voltage than the upper threshold set by VR3.

During emergency stop signalling (after the upper threshold is reached), the RA1 output is switched low (toward 0V) and high (toward 5V) at 3.85Hz to flash LED1 which is blue.

Note that an off-board LED can be used instead, connected via CON5. If an external red or yellow LED is used, it will shunt LED1's current and so the external LED will light but LED1 will not, because a red or yellow LED has a lower forward voltage than a blue type.

Or alternatively, simply omit LED1 and use whatever colour of external LED you want.

Output RA0 is driven identically to RA1, to drive the gate of Mosfet Q2 which switches RLY2 on and off

Where do you get those HARD-TO-GET PARTS?

Many of the components used in SILICON CHIP projects are cutting-edge technology and not worth your normal parts suppliers either sourcing or stocking in relatively low quantities. Where we can, the SILICON CHIP PartShop stocks those hard-to-get parts, along with PC boards, programmed micros, panels and the other bits and pieces to enable you to complete your SILICON CHIP project.

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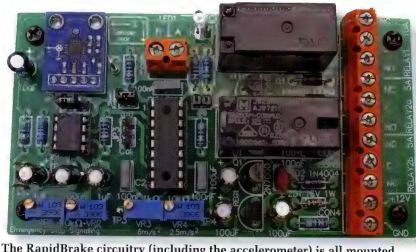

The RapidBrake circuitry (including the accelerometer) is all mounted on a single PCB measuring 106 x 58.5mm (shown here about life size). All connections are made via the terminal blocks on the right side. Complete constructional details and setup will be presented next month.

at 3.85Hz. At the same time, output RA7 goes high while RA0 and RA1 are being pulsed. RA7 drives Mosfet Q1 to switch on RLY1.

RLY1 is therefore latched for the entire duration of the emergency stop signalling period; it does not switch on and off at 3.85Hz.

So why have two relays?

Relay RLY1 is used when the hazard lights are used for emergency stop signalling.

It's used to disconnect the normal control signals from the indicator lamps, so that they do not interfere with the RapidBrake's use of those same lamps. While RLY1 disconnects those lamps from the vehicle, RLY2 then switches them on and off at 3.85Hz.

Alternatively, if the brake lights are being flashed, RLY1 is not used and RLY2 flashes the brake lights at 3.85Hz; they will have already been switched by the brake pedal switch.

When deceleration drops below the lower threshold, output RA1 goes high to switch off LED1 and outputs output RA0 & RA7 go low to switch off the two relays. Diodes D1 and D2 quench the voltage spike that occurs when the relay coils are switched off.

Calibration circuitry

There are several jumper links to provide for calibration. JP2, for example, is used to set the quiescent voltage reading at AN2 and AN3, with the accelerometer module on a level surface.

This provides the reference voltages against which the software calculates change in voltage from the Z output and the X or Y output for angles off horizontal.

We'll look at calibration in more detail once we have finished the construction details next month.

Power supply

Power for the RapidBrake comes via the vehicle's ignition switch and passes through diode D3 to provide the supply for the relay coils (V+). REG1 is used to provide a stable 5V rail for op amp IC1 and microcontroller IC2.

This is important to maintain accelerometer accuracy since the output voltages of dual op amp IC1 are supply dependent, since VR1 and VR2 connect across the 5V supply. The ADC in IC2 also uses the 5V rail as a reference voltage.

Parts list – RapidBrake

1 double-sided PCB coded 05105171, 106 x 58.5mm
1 UB3 plastic utility Jiffy box, 129 x 68 x 43mm (Jaycar HB-6023, Altronics H0153)
1 3-axis accelerometer module (Jaycar XC-4478)
1 12V SPDT 10A relay (Jaycar SY-4050, Altronics S4197) (RLY1)
1 12V DPDT 5A relay (Jaycar SY-4052, Altronics S4270A) (RLY2)
3 3-way screw terminals with 5.08mm spacing (CON1-CON3)
2 2-way screw terminals with 5.08mm spacing (CON4,CON5)
1 18-pin DIL IC socket
1 8-pin DIL IC socket (optional)
2 cable glands for 6mm diameter wiring
1 snappable 10-way pin header (JP1-JP3)
2 2-pin shorting plugs
4 6.3mm long M3 tapped Nylon spacers
4 M3 x 6mm machine screws
4 M3 x 5mm machine screws
7 PC stakes (TP1-TP5,GND & +5V)

Semiconductors
1 LMC6482AIN dual CMOS op amp (IC1; Jaycar ZL3482)
1 PIC16F88-I/P microcontroller programmed with 0510517A.hex (IC2)
1 LP2950ACZ-5.0 5V low drop out regulator (REG1; Jaycar ZV1645)
2 2N7000 NPN Mosfets (Q1,Q2; Jaycar ZT2400)
3 1N4004 1A diodes (D1-D3)
1 16V 1W zener diode (ZD1)
1 3mm blue LED (LED1)

Capacitors
4 100µF 16V PC electrolytic
2 10µF 16V PC electrolytic
1 1µF 16V PC electrolytic
3 100nF MKT polyester
1 100nF ceramic

Resistors (0.25W, 1%, through-hole)
1 43kΩ 2 10kΩ 1 470Ω 4 47Ω
3 10kΩ top adjust multi-turn trimpots (VR1,VR2,VR4)
1 1kΩ top adjust multi-turn trimpots (VR3)

REG1 is protected against transients (a vehicle supply is never "clean"!) using a 47Ω resistor from the V+ supply, a 100µF bypass capacitor and zener diode ZD1 that clamps its input voltage at 16V.

Next month

If you're interested in building the RapidBrake, you can order the PCB from the SILICON CHIP online shop (catalog code SC4321) and start gathering the parts, as laid out in the parts list in this issue.

The programmed PIC is also available from the SILICON CHIP online shop (catalog code SC4322); all other components should be readily available from your normal suppliers.

Next month we'll go through the process of assembling the PCB, calibrating it, putting it in the case, mounting it in the vehicle, wiring it up and testing it. SC

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	43kΩ	yellow orange orange brown	yellow orange black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	1	470Ω	yellow purple brown brown	yellow purple black black brown
❑	4	47Ω	yellow purple black brown	yellow purple black gold brown

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Higher power, loads more features . . .

Deluxe, higher spec eFuse

Part one: by Nicholas Vinen

No sooner had the eFuse article (April 2017) hit the streets than readers were asking, "Great – but what about (fill in the gaps!)?" So we decided to produce a deluxe version of the eFuse which filled in just about every gap we could think of: higher voltage, higher current, single-ended or bipolar, a touch-screen interface, selectable time constants, a real-time voltage, current and tripping display. It's based on the tried-and-tested Micromite LCD BackPack.

This deluxe eFuse/DC circuit breaker acts like one or two DC fuses, except that these fuses can be "magically" restored once they "blow", at the touch of the screen, potentially saving you a lot of money and hassles.

If you decide you need a different fuse value or blow speed, you can simply change it on the fly.

And unlike a normal fuse, this one shows you how close to blowing it is at any given time.

It's especially valuable when you are building or repairing equipment since you can set the fuse "blow" (trip) current low initially, switch on and see what happens.

If it doesn't blow then you can wind up the trip current and increase the load and/or activate more features in the device you're testing, progressively checking each function.

If something goes wrong, the eFuse will very quickly cut the power off and you can then figure out what the problem is, without letting any of the smoke out.

As we mentioned earlier, we published a simple eFuse DC circuit breaker project in our April 2017 issue. That one was a small and low-cost device that was quite easy to build.

However, it had limited voltage (16V) and current (10A) capability and you had to change one or two fixed resistor values to adjust the trip current.

It also had no display of any sort, apart from LEDs indicating the presence of power and whether the fuse had "blown" or not.

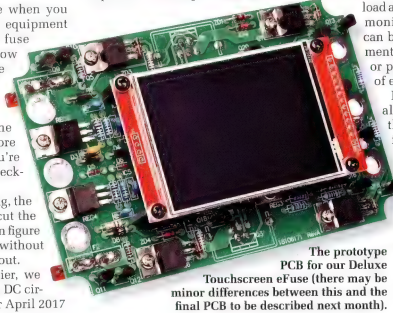
This new and much fancier eFuse is more complex, larger and more expensive but it provides a lot of extra features to make up for that.

Just look at the many features and specifications listed in the adjacent panel, starting with the higher maximum voltage (32V), much higher current capability (25A+), split supply capability, easy trip current setting via touch-screen and the real-time display of voltage, current and simulated fuse temperature to save you the hassle of hooking up a bunch of multimeters so you know just what's going on.

Basically, it's a comprehensive DC load and supply protection and monitoring solution which can be used in a lab environment or as a semi-permanent or permanent part of a piece of equipment.

Despite all its features, all the components are through-hole types and fit on a modestly sized (132 x 85mm) PCB which itself fits into a low-cost UB1 jiffy box.

One bonus feature that you don't get with regular fuses is that if you are using it with a split supply, for example, when testing an audio amplifier (albeit with a maximum supply voltage



The prototype PCB for our Deluxe Touchscreen eFuse (there may be minor differences between this and the final PCB to be described next month).

Features and Specifications

Function:	DC circuit breaker
Operating modes:	positive supply breaker only, positive and negative supply breaker with independent trip, positive and negative supply breaker with simultaneous trip
Working voltage range:	12-32V or ±12-32V
Normal trip current:	selectable from 0.1A to 30A in 0.1A steps
Instantaneous trip current:	>68A for >1ms
Continuous current handling:	25A; automatic switch-off at elevated temperature
Series resistance:	approximately 16 milliohms per channel
Voltage loss:	<0.25V at 10A; <0.5V at 20A; <0.75V at 30A
Quiescent current:	~50mA (operating, with screen off)
Quiescent dissipation:	~0.5-2W depending on supply voltage and LCD backlight brightness
Extra dissipation:	~2.5W per channel at 10A; ~7W per channel at 20A; ~10W per channel at 25A
Trip response time (selectable):	fast (~10ms for 2x overload), normal (~100ms for 2x overload) or slow (~1s for 2x overload)
Read-outs (with screen on):	positive and negative input voltage, positive and negative current flow, breaker trip bar graphs (indicates how close to tripping each channel is), breaker state for each channel
Extra features:	soft start, touchscreen configuration, non-volatile settings, start-up on/off/last state, complete input and output protection with one-way current flow, brief transient protection, overheating protection, binding posts for supply and load connections, adjustable screen brightness, screen auto-off, built-in diagnostics with under-voltage lockout, safety protection fuses

of ±32V), you can program it so that if either rail draws too much current, they will both be switched off simultaneously.

This will often prevent one fault from cascading into several, in the case where the DC fuse in one rail blows but the other does not.

We can't guarantee it but this eFuse may react fast enough to sudden high current draw to prevent the destruction of output transistors; it's well known that conventional fuses are not fast enough (the output transistors "blow to protect the fuses" [!]).

Our eFuse can react in well under 1ms when set to its most sensitive mode, so it might just save you some expensive transistors...

The input and output connections are made via high-current binding posts and you can use banana plugs for currents up to about 10A and bare wires for higher currents.

We've made an effort to minimise its additional power supply current drain and internal dissipation, although it will (unavoidably) get a little warm if operated for long periods near its maximum rated current.

Touchscreen control

The Micromite is part of the reason why we're able to provide so many features with a modestly complex circuit. Many of the additional features have been provided with software, rather than additional circuitry. And the touchscreen makes it easy to set up and use.

General operating principle

Refer to the simplified circuit/block diagram, shown in Fig.1.

The fundamental tasks required for an electronic fuse/DC circuit breaker are to monitor the current flowing between the input and output terminal(s) and to be able to stop the current flow if it exceeds the programmed limit for long enough (with a progressive overload response more or less approximating that of a real fuse or circuit breaker).

To achieve this, the two main parts of the circuit are N-channel "SenseFET" Mosfets Q1 and Q3 and the Micromite LCD BackPack (equivalent) circuitry.

The Mosfets have a dual role: they allow us to efficiently monitor the current flow and also to interrupt that current flow should it become excessive.

We explained SenseFETs in some detail in the April 2017 eFuse article, as this type of device was contained within the ICs used in that project.

But this is the first time we're using discrete SenseFETs, so they deserve a brief explanation.

Essentially, a SenseFET is two Mosfets, one large and one small, connected in parallel in a single package.

Because their construction is similar, current flowing through the device is split proportionally between the two.

Fig.2 shows the basic arrangement. At left (Fig.2a) it shows how current flow is measured with a traditional Mosfet. The value of resistor "R" normally needs to be very low, say 1mΩ, in order to avoid very high dissipation.

Even a 5mΩ resistor would dissipate nearly 5W with 30A flowing through it, and yet the full-scale sense voltage would be just 150mV. That's far from an ideal situation and a lot of power to waste.

However, in reality, a high-power Mosfet is actually multiple, smaller Mosfets in parallel. Fig.2b shows how two would be paralleled but it's many more than that. This works because they are all on the same die and all virtually identical, so current is shared between them.

The SenseFET takes this one step further, as shown in Fig.2c; the majority of smaller Mosfets are paralleled to provide one main Mosfet which

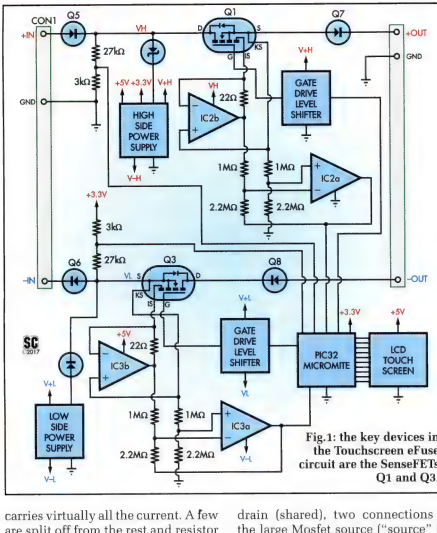


Fig.1: the key devices in the Touchscreen eFuse circuit are the SenseFETs Q1 and Q3.

carries virtually all the current. A few are split off from the rest and resistor R can be inserted in series with their source terminal.

Since a small fraction of the load current flows through this resistor, it can have a much higher value, giving a higher and more practical voltage reading while dissipating much less power, because most of the load current bypasses it entirely.

As long as the Mosfets share current in fixed proportions, this scheme provides accurate current measurement with far fewer drawbacks compared to the scheme shown in Fig.2(a).

In the case of the BUK7909 devices used here, the current split ratio is very close to 1:999, so in other words, current through the small Mosfet is 1/1000th that of the total current flow. This means that 99.9% of the current does not pass through this resistor, minimising voltage and power losses.

The BUK7909 is supplied in a TO-220 package with five pins. A typical Mosfet has three pins: gate, drain and source. The BUK7909 has one gate (shared by both internal Mosfets), drain (shared), two connections to the large Mosfet source ("source" [S] and "Kelvin source" [KS]) and the small Mosfet source ("Isense" [IS]), as depicted in Fig.1.

The Kelvin source connection is provided so that we can accurately measure the voltage at the larger Mosfet's source even when a high current is flowing through its lead which will cause a voltage drop due to its inherent resistance.

Now, while we showed the bottom end of the source resistor connecting to the main Mosfet's source in Fig.2(c), for maximum accuracy, the two Mosfet source terminals must be kept at the same voltage, despite the sense resistor in series with the small Mosfet.

Op amp maximises accuracy

An increase in the voltage at IS compared to S/KS would mean that the two parallel Mosfets would have different gate-source voltages and thus the current split would not necessarily be 1:199.

To solve this, as shown in Fig.1, op amp IC2b monitors the voltage at KS and drives the bottom end of the sense resistor to maintain identical voltages at KS and IS.

However, this is not easy to arrange. The op amp's negative supply rail must be far enough below the source voltage to allow it to produce the required voltage across the sense resistor. This actually is more of a problem for IC3b/Q3 since Q3's source terminal is at the fully negative supply voltage when it is in conduction.

Also, the sense op amps must be able to handle the maximum current that can flow through the 22Ω resistor. Even at 1/1000th of the full current, that's still up to 68mA for a 68A total peak current.

We achieve this by using an emitter-follower transistor buffer at the op amp output (not shown in Fig.1). The op amp automatically cancels out the added base-emitter voltage because of the negative feedback.

The op amp negative voltage supply must also be capable of delivering 68mA. If the op amp or supply can't deliver 68mA, that could potentially result in an under-reading of the actual current flow and the fuse may not trip on an overload; that would be bad!

Because the current through the sense resistor does not flow to the output of the device, this effectively means a 0.1% increase in current drawn from the supply compared to that which is supplied to the load (in addition to the device's quiescent current).

The output of op amp IC2b is a voltage which is initially the same as the source voltage of Q1 when there is no current flow (ie, VH minus the voltage drop across Q1) and the voltage drops as current flow increases.

So that the microcontroller (which runs off a 3.3V rail) can sense this voltage, the other half of the dual op amp, IC2a, is used as a differential amplifier.

It has a gain of 2.2 times, as determined by the ratio of 2.2MΩ and 1MΩ resistors and its output is the difference between the voltage at the KS terminal of Q1 and the output of IC2b, multiplied by 2.2.

So its output is 0V for no current flow, rising to around 3.3V for a current flow of 68A (68A ÷ 1000 x 22Ω x 2.2 = 3.29V). This is fed to the onboard Micromite microcontroller.

This micro also monitors the voltage at VH, via a 27kΩ/3kΩ resistive divider, which divides the input voltage by

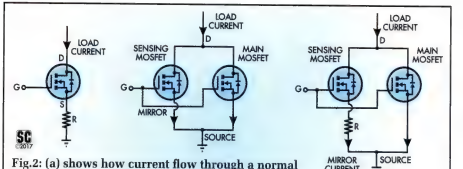


Fig.2: (a) shows how current flow through a normal Mosfet can be sensed with a series resistor. (b) shows how a small and large Mosfet can be paralleled within a single device, with the load current split between them, with a ratio dependent on the size of the two Mosfets. (c) expands this concept to include a resistor in series with the smaller "sensing" Mosfet, allowing us to monitor the overall current while keeping power and voltage losses low.

a factor of ten. This is used primarily for display purposes.

It also monitors the V+H rail (not shown in Fig.1) and will refuse to operate unless it's high enough to allow Q1 to be switched on properly.

The micro controls Q1 via level shifter circuitry, shown here as a "black box". This pulls the gate of Q1 up to V+H when it is to be switched on, which is around 10V above VH. The gate voltage drops to around 15V below VH to switch Q1 off. Its default condition is off.

The circuitry to monitor the current through Q3 essentially mirrors that to monitor Q1, with a few minor differences.

Firstly, Q3's source goes to the input side, rather than the output side, as it controls current flow in the opposite direction. Op amp IC3 runs off supply rails of +5V and V-L (around 6V below VL), compared to the V+H and GND supply for IC2.

The gate drive level shifter for Q3 drives it high to V+L (around 10V above VL) and low, to VL.

Choice of op amps

IC2 and IC3 are LT1490A dual "Over-The-Top" op amps from Linear Technology. These were chosen for very specific characteristics which few op amps possess and that are required in this circuit.

We have a detailed review of these devices (and the very similar LT1638) on page 60 of this issue.

They have rail-to-rail input and output voltage ranges, with the output able to produce voltages just a few millivolts above the negative rail.

This is important since IC2a needs to be able to produce an output very close to 0V when there is no current flowing through Q1 and its negative supply rail is GND.

To use an op amp without this capability would require a more complex power supply, to produce a -1V rail for IC2's negative supply (or something like that).

Very few rail-to-rail op amps will operate at up to 44V but these op amps will. That makes them ideal for level-shifting and differential amplifier circuits which need to handle relatively high input voltages, like this one.

Also, the quiescent currents of IC2 and IC3 are very low at about 0.1mA, so they minimally load the V+H and V-L supply rails, both of which are provided by charge pumps which have a relatively high output impedance and thus their voltages could drop under significant load.

IC3a's positive supply is the 5V rail because if we used the 3.3V rail, it wouldn't be able to produce output voltages above about 3V; the LT1490 isn't as good at swinging to the high supply as it is to the low supply rail.

To keep its total supply voltage below the 44V limit, that means V-L can't go below -39V with the maximum VL voltage of -32V (or -33V to be safe).

This has been achieved by making the charge pump that generates the V-L rail purposefully "lossy" (as will be explained below) so that its typical unloaded voltage with VL=-33V is pretty much exactly -39V.

Zero voltage "diodes"

We haven't mentioned the "diodes" labelled Q5, Q6, Q7 and Q8 yet. These are "ideal diodes" in the sense that they have virtually no voltage across them when they are in forward conduction.

As you may have guessed (since they're labelled "Q"), while they are shown as diodes, they are actually Mosfets which are made to act like diodes.

So why are these Mosfets/diodes included?

Firstly, with a single SenseFET to control the current flow between each input/output pair, we can only block current in one direction.

So without additional protection, if you accidentally mixed up the input and output terminals, the circuit could not be broken and so the eFuse and/or load could be damaged.

These four "diodes" prevent current flow in this case. They also protect the unit against accidentally reversed supply polarity, especially for the input terminals. They will be explained in more detail later.

Control and power supply

As you may have gathered, our circuit has two negative supply generators since we need to monitor two SenseFETs with different source voltages (for positive and negative supply situations).

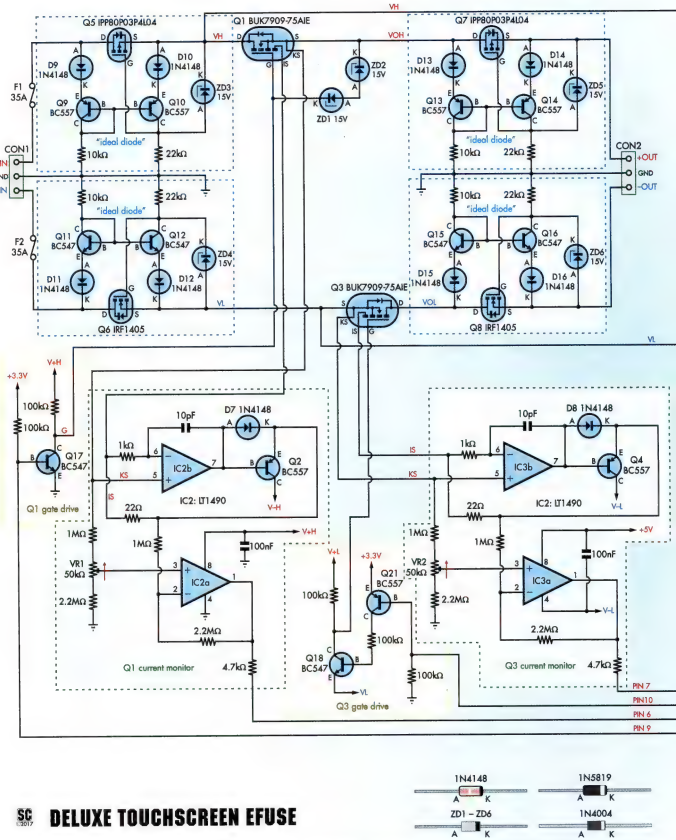
It also has a boosted positive supply generator for the upper SenseFET, to generate a sufficiently high voltage (above the positive input supply) to bring its gate high enough for full conduction.

The high-side power supply contains three linear regulators and one charge pump. The linear regulators generate a +5V rail for the touchscreen and a +3.3V rail for the microcontroller.

These rails are also used for other purposes. The third linear regulator derives a V-H rail 10V below VH. This is then inverted by the charge pump, to produce a V+H voltage about 6V above VH, used primarily for Q1's gate drive.

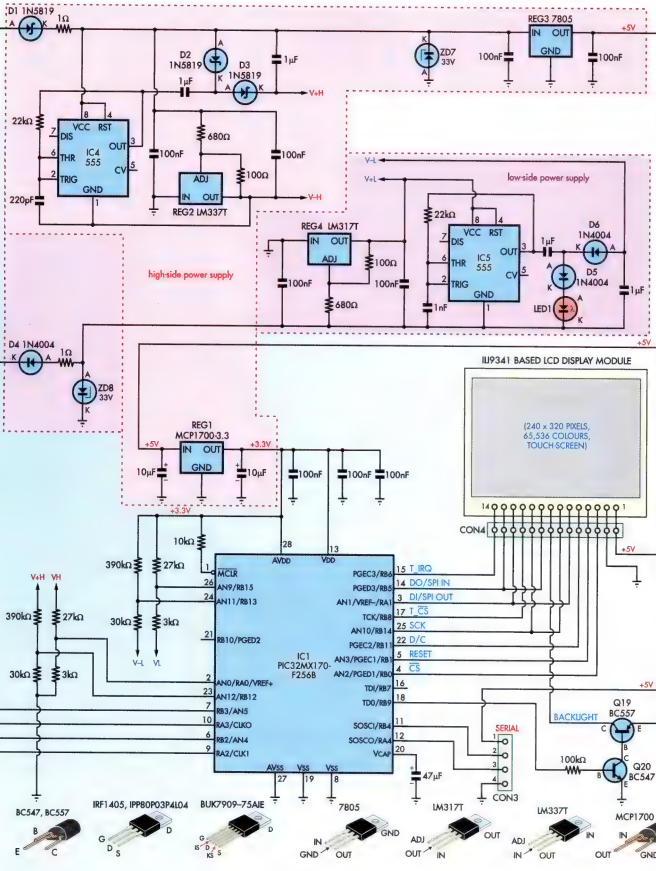
The low-side power supply contains one linear regulator and one charge pump. The linear regulator is used to derive V+L, about 10V above VL, which is primarily used for Q3's gate drive. This is inverted by the charge pump to derive V-L, above 10V below VL, used for op amp IC3's negative supply.

Two simple level-shifting transistor circuits allow the microcontroller to bring the Mosfet gate voltages high to switch on the SenseFETs for normal operation.



DELUXE TOUCHSCREEN EFUSE

Fig.3: the complete circuit diagram. You can relate the shaded boxes to various elements in Fig.1; see the labels within. The "ideal diode" sections behave similarly to diodes but with almost zero forward voltage (about 5mV/A). The red and mauve power supply sections generate the voltages required to run op amps IC2 and IC3 and also to drive the gates of Q1 and Q3 to the correct voltages to switch them on fully.


D1 1N5819
1Ω
D2 1N5819
D3 1N5819
1µF
ZD7 33V
REG3 7805
IN OUT
GND
+5V
100nF
V+H
22kΩ
IC4 555
VCC RST
DIS
THR
TRIG
OUT
CV
GND
220pF
680Ω
100Ω
ADJ
REG2 LM337T
V+L
low-side power supply
REG4 LM317T
IC5 555
D6 1N4004
D5 1N4004
1nF
LED1
high-side power supply
D4 1N4004
ZD8 33V
ILI9341 BASED LCD DISPLAY MODULE
(240 x 320 PIXELS, 65,536 COLOURS, TOUCH SCREEN)
CON4
REG1 MCP1700-3.3
+3.3V
10µF
10kΩ
390kΩ
27kΩ
30kΩ
3kΩ
V-H
V-L
V+L
IC1 PIC32MX170F256B
AVDD
VDD
MCLR
AN9/RB15
AN11/RB13
RB10/PGED2
AN0/RA0/VREF+
AN12/RB12
RB3/AN5
RA3/CLKO
RB2/AN4
RA2/CLK1
AVSS
VSS
PGEC3/RB6
PGED3/RB5
AN1/VREF–/RA1
TCK/RB8
AN10/RB14
PGEC2/RB1
AN3/PGEC1/RB3
AN2/PGED1/RB0
TDI/RB7
TDO/RB9
SOSCI/RB4
SOSCO/RA4
VCAP
T_IRQ
DO/SPI IN
DI/SPI OUT
T_CS
SCK
D/C
RESET
CS
BACKLIGHT
Q19 BC557
Q20 BC547
100kΩ
SERIAL
CON3
47µF
BC547, BC557
IRF1405, IPP80P03P4L04
BUK7909-75AIE
7805
LM317T
LM337T
MCP1700

These circuits are biased so that the Mosfet gates are pulled low by default, so that no current flows until the microcontroller is ready and supervising the current flow.

If the micro then resets for any reason (eg, a supply voltage drop-out or software error), the current flow is interrupted and the load is switched off.

Circuit description

The full circuit of the Touchscreen eFuse is shown in Fig.3. You should be able to see the similarity between its upper-left quadrant and the simplified circuit/block diagram of Fig.1.

The internal structure of the four "ideal diode" sections is now visible, each within a blue shaded box.

Q5 and Q7 are P-channel Mosfets while Q6 and Q8 are N-channel Mosfets, to suit their low-side and high-side situations respectively.

The control circuitry for each of those four Mosfets is identical, except it is mirrored for the N-channel Mosfets compared to P-channel Mosfets, ie, NPN driver transistors rather than PNP and so on.

The Mosfet types have been chosen to have similar characteristics, critically, a breakdown voltage of at least 30V, a continuous current rating of more than 50A and an on-resistance no more than about 5mΩ, to keep losses low, even at high currents.

Looking at the circuitry around Q5, PNP transistors Q9 and Q10 are arranged so that they are constantly "comparing" the voltage across Q5's channel. Diodes D9 and D10 protect Q9 and Q10 from reverse breakdown of their base-emitter junctions in case of reversed supply polarity.

Since the current through these small-signal diodes is similar, their forward voltage will be similar and hence a difference in voltage between Q5's drain and source terminals appears as a difference in voltage between the emitters of Q9 and Q10.

Q9 has its base and collector joined, effectively making it a diode, which is forward-biased by current flowing through its 10kΩ collector resistor. As Q9 and Q10 are the same transistor types, so if Q5's source voltage is lower than its drain voltage, Q10's base-emitter voltage is too low for it to switch on fully and the 22kΩ collector resistor pulls the gate of Q5 to ground, switching it on.

Current can therefore flow from the +IN terminal of CON1 to Q1 (ie, "VH"), as long as the +IN voltage is above VH, ie, current is flowing from left to right. Zener diode ZD3 prevents Q5's gate from being more than 15V lower than its source terminal; a much higher gate-source voltage than that could break down Q5's gate insulation and ultimately, damage it.

Should the voltage at Q5's source rise above that of its drain, the base-emitter voltage of Q10 becomes higher than that of Q9 and hence Q10 switches on, bringing Q5's gate high and thus cutting it off. This prevents current flow from right to left through Q5.

While this is a linear circuit and thus could theoretically drive Q5 into partial conduction, which could result in very high dissipation, in practice this will not happen.

That's because, in partial conduction, the voltage across Q5 becomes very high and the higher the voltage differential, the more Q5's gate is driven either up to its source voltage or down towards 0V, switching it either fully off or fully on. So essentially, this circuit is stable only in one state or the other, not in between.

Q5's intrinsic diode is orientated in the normal direction of current flow. If the supply polarity is reversed, Q5's gate remains discharged and so current can not flow. We won't describe the other three "ideal diode" blocks since they all operate identically.

Current sensing details

The two current sense circuit blocks, shaded in green, operate as shown in Fig.1, however, there are a number of circuit details which were hidden in that simplified diagram.

Firstly, there is the current buffering arrangement at the output of IC2b (Q2) and IC3b (Q4). These emitter-followers ensure that the op amps can sink at least 100mA. The op amp negative feedback automatically compensates for the ~0.7V drop across each base-emitter junction.

The collector of each transistor is connected to V-H and V-L in turn. Since op amp IC2b's negative rail is at 0V, well below VH and IC3b's negative rail is V-L, 10V below VL, in both cases the bottom end of the 22Ω sense resistor can be driven well below the respective source voltage, so that IS=KS during normal operation.

Diodes D7 and D8 prevent the base-emitter junctions of Q2 and Q4 respectively from becoming reverse biased when Q1/Q3 are switched off. The 10pF capacitors between the output and inverting input of each op amp prevent oscillation due to the capacitance and phase shift of the added emitter-followers.

The differential amplifiers/level shifters based around IC2a and IC3a are quite simple and almost identical. In both cases, a resistive divider is connected between KS and ground, and the junction of the two resistors is connected to the non-inverting input, pin 3. There is a similar divider between the negative end of the 22Ω sense resistors, the pin 2 inverting input and the pin 1 output.

These two pairs of resistors have the same division factor of 0.3125 times (1M ÷ [1M + 2.2M]). Trimpots VR1 and VR2 are included in the middle of one divider so that you can trim them to give exactly the same division ratio, so that the output of IC2a/IC3a is at 0V when there is no voltage across the 22Ω resistors (ie, no current flow through Q1/Q3). This provides a high common mode rejection ratio (CMRR), preventing changes in the supply voltage from affecting the current measurements.

Consider how IC2a operates. The voltage at pin 3 is 0.3125 times KS (which is the same as VOH, the high-side output voltage). If there is no current flowing, with no voltage across the 22Ω resistor and KS=IS, the top of the 1MΩ resistor connected to pin 2 is at the same potential as KS.

Therefore, to have the same voltage at pin 2 as pin 3, the bottom end of that divider needs to be at GND potential, just like the identical divider connected to pin 3. This will be when the pin 1 output is at 0V.

Hence, negative feedback determines that pin 1 is at 0V when no current is flowing. When current does flow, the voltage across the 22Ω resistor causes the voltage at pin 2 to drop.

But the voltage at pin 3 has not changed, so output pin 1's voltage must rise in order to keep the voltage at pin 2 and pin 3 the same. Hence, the output voltage increases as the current flow increases. The 2.2MΩ feedback resistor's ratio with the 1MΩ resistor means that the overall gain is 2.2 times.

The outputs of IC2a and IC3a are fed to analog inputs AN4 and AN5 of microcontroller IC1 via 4.7kΩ resistors, which limit the current flow in case these pins are over-driven. Since

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IC1 has a 3.3V supply, this is the maximum voltage which can be read at those inputs. Given the 2.2 times gain, that equates to a maximum voltage across the 22Ω resistors of 1.5V (3.3V ÷ 2.2) .

That equates to a current flow of 68mA (1.5V ÷ 22Ω) and given the 1000:1 current sense ratio, a maximum sense current of 68A.

Anything higher than this will simply read as 68A, hence we have set the instantaneous (~1ms) trip current to this level since the actual current flow could be higher and the safety protection fuses (F1 and F2) could blow if this is not interrupted, along with possibly Q1 and Q3 being damaged.

Gate drive

NPN transistor Q17 is biased on by default, by a 100kΩ resistor from its base to the 3.3V rail. This pulls Q1's gate down to 0V, keeping it off, although it is clamped to about 16V below VOH to protect Q1.

When Q1 is off, VOH tends towards 0V as no current can flow through it, so ZD1/ZD2 will not normally conduct for very long. The current through them is normally limited to about 10mA (3.3V ÷ 100kΩ x 300 – typical beta for Q17) .

When microcontroller IC1 wants to switch Q1 on, it pulls its RA2 output low, switching off Q17 and allowing the 100kΩ resistor to V+H to pull Q1's gate above VH/VOH. The relatively high 100kΩ value combines the Q1's gate capacitance of around 10nF to provide a "soft start" time of about 1ms (100kΩ x 10nF).

This prevents very high current surges into capacitive loads, although switch-on current flow could still be enough to trip the eFuse, depending on how it's configured (just like a normal fuse or circuit breaker).

The gate drive for Q3 is a little different. PNP transistor Q21 is normally switched on due to the 100kΩ pull-down resistor at its base. It, in turn, supplies current to the base of NPN transistor Q18 which has its emitter tied to VL, normally below 0V. This pulls Q3's gate down to VL, which is its source voltage, hence keeping it off.

To switch on Q3, microcontroller IC1 brings its RA3 output high, forcing Q21 to switch off and in turn, Q18 loses its base current. This allows Q3's gate to be pulled up to V+L via the 100kΩ resistor, again giving a soft-start time of around 1ms. No gate protection is needed since V+L is never more than 15V above VL.

Voltage monitoring

The VH and VL input supplies are monitored by IC1 primarily so that they can be displayed for the user. However, they are also used to provide the under-voltage lockout function, where IC1 will refuse to switch on Q1 and Q3 if the relevant supplies are not high enough to guarantee correct operation. Normal operation starts with a supply voltage of at least 11V and will continue as long as the supplies do not drop below 10V.

VH is divided by a factor of ten using 27kΩ and 3kΩ resistors and applied to analog input AN0 of IC1 (pin 2). Thus, it can read up to 33V. The 3.3V supply is used as a reference; the MCP1700 regulator has a typical error of ±0.4% at 25°C, so calibration is not critical although the software does allow you to calibrate the readings for high accuracy.

V+H is also monitored, in a similar manner, although the divider resistors are 390kΩ and 30kΩ.

The higher values are to reduce the loading on the V+H rail as it has limited current delivery and the division ratio has been increased to one-fourteenth, since the V+H rail can range up to about 42V (not coincidentally, just below the maximum recommended supply voltage for the LT1490 op amps of 44V).

The arrangements for monitoring the VL and V-L rails, at analog inputs AN9 (pin 26) and AN11 (pin 24) are basically the same, except the "far end" of the divider goes to +3.3V rather than ground; this is to keep the voltages at these pins between 0V and 3.3V. The software subtracts 3.3V from the readings at the same time as compensating for the divider values, to get true voltage readings.

Monitoring V-L and V+H has three purposes. One, it provides a debugging feature; if the power supply is not built properly, IC1 will detect this and display a message on the screen.

Two, it protects the unit against damage in case either or both boosted rails drop below the minimum required for correct operation, in which case the outputs will automatically be tripped and a message displayed. This should not normally happen and could indicate a faulty component or that the power supply voltage dropped too much under load.

Finally, it allows the microcontroller to fairly accurately model the dissipation in Mosfets Q1, Q3 and Q5-Q8 during operation and track their assumed temperatures. The unit will then shut down the outputs if any is at risk of serious overheating.

While the unit can be configured with a trip current of up to 35A, we've quoted a continuous current handling rating of 25A since both Q1 and Q3 will be dissipating 4.7W (25A x 25A x 7.5mΩ) at 25A. That's fairly substantial, despite them having flag heatsinks, especially in a plastic jiffy box and especially if high currents are being drawn from both outputs.

With a sustained current of say 30A, the unit may not trip normally but the Mosfets could still get very hot. So the unit will trip to prevent overheating and damage and will display a message on the screen indicating this.

Power supply details

The high-side power supply, responsible for generating the +3.3V, +5V, V+H and V-H rails, is shown in the red shaded box.

Schottky diode D1 is used even though there is an "ideal rectifier" between +IN and the VH rail so that brief drops in the incoming supply voltage, due to high load current (eg, at initial switch-on of a capacitive load) to not cause the supply rails to drop too quickly.

The 1Ω resistor and 33V zener diode ZD7 combine to filter out very brief spikes which may occur, for example, due to back-EMF from a motor load, protecting linear regulators REG2 and REG3.

REG2 is an LM337 negative adjustable linear regulator. The 680Ω and 100Ω feedback resistors set its output voltage very close to 10V below VH.

In this case, its "input voltage" is ground and its "ground" voltage is VH. This produces the V-H rail. REG2 is in a TO-220 package which uses the PCB as a heatsink, since it may need to (briefly) supply up to 100mA with a 22V input-output differential which works out to a dissipation of 2.2W.

555 timer IC4 is connected between VH (after D7) and V-H, ie, the output of REG2. So with a +IN voltage of say +24V, its V_{CC} pin will be at around +23V while its GND pin will be at around +13.7V (ie, 10V below V_{CC}).

Since its output (pin 3) is connected via a resistor to the threshold and trigger inputs (pins 6 and 2 respectively), it will oscillate with a 50% output duty cycle; each time the output switches high, this will charge the 220pF capacitor between pins 1 and 2 until pin 6 reaches 2/3 its supply voltage. The output will then switch low and discharge that same capacitor until it reaches 1/3 the supply voltage, then the output will switch high again and the process will repeat.

The time constant of the 22kΩ resistor and 220pF capacitor sets the oscillation frequency to around 100kHz.

Each time output pin 3 goes low, the 1µF capacitor charges to around 9.7V, via schottky diode D2 from VCC. When output pin 3 goes high, the anode of schottky diode D3 is raised to around 9.7V above VCC and so D3 is forward-biased and the 1µF capacitor between VCC and V+H charges. The result is that V+H tends towards around 9.4V above VCC, ie, around 9V above VH.

The remainder of the high-side supply is quite simple, with 5V linear regulator REG3 producing the +5V rail for the LCD touchscreen and op amp IC3 and this is also fed to REG1 to produce the +3.3V rail for microcontroller IC1.

Because the combined total of these currents can exceed 100mA and because the input to REG3 can be up to about 32V, giving a differential of 27V and a dissipation in excess of 3W, REG3 uses the PCB as a heatsink.

The software automatically limits LCD brightness with a high supply voltage to ensure REG3 doesn't overheat and "drop its bundle" (go into thermal limiting, likely shutting down the whole device).

The low-side power supply more or less mirrors the high-side supply, although without the 5V and 3.3V regulators. It is shown shaded in mauve.

Diode D4 is a cheaper 1N4004 standard diode rather than a schottky diode (like D1) since the critical V+L supply which is used to drive the gate of Mosfet Q3 does not rely on the charge pump and so it has a lower effective dropout voltage. Thus the extra forward voltage of D4 is not a major issue.

V+L is derived in a similar manner to V-H, only using an LM317 positive regulator rather than an LM337 negative regulator. V+L sits about 9.3V above VL. This is then fed to another 555 timer, IC5, which inverts this voltage in a similar manner as described above for IC4. The result is V-L, which is around 6V below VL.

As we mentioned earlier, this is a purposefully lower supply voltage than V+H in order to keep IC3a within its maximum supply rating of 44V (ie, V-L can not exceed -39V).

This is achieved by using 1N4148 standard signal diodes in the charge pump, rather than 1N5819 schottky diodes, each adding about 0.5V further voltage drop, plus red LED1 in series with D5 for an additional voltage drop of around 1.8V.

The full load current of IC5 must pass through LED1, which equates to just over 30mA with a load current through Q3 of 30A.

As a result, we specify a current rating for LED1 of 50mA, which is available in a 3mm package from Jaycar. This is pretty safe, since a sustained Q3 current of 50A will pretty quickly trip the output off, also protecting LED1.

Microcontroller and touchscreen

The arrangement of IC1, REG1 and the LCD touchscreen is copied directly from the Micromite LCD BackPack, a standalone project which was published in the February 2017 issue.

While we could have designed this unit to use the BackPack as a plug-in module, we decided that integrating the circuit onto the main PCB would save cost.

The same kit of parts can be used to build this section of the board, minus the BackPack PCB and laser-cut lid (since the box used in this project is bigger).

There isn't much to the BackPack; besides the power supply, there's just PIC32 microcontroller IC1, its 10kΩ MCLR-bar pull-up resistor that prevents spurious resets, the bypass capacitors and required core filter capacitor between pin 20 of IC1 and ground, a 4-pin serial interface connector (CON3) and the 14-pin female header for the LCD touchscreen to plug into (CON4).

IC1 communicates with the LCD using two SPI interfaces, one to send commands and data to the LCD and one to interface with the onboard touch sensor IC.

They share three wires: pin 25, the SPI clock, pin 3, the SPI OUT data line (which goes to the data inputs of the LCD controller and touch controller) and pin 14, the SPI IN data line (which goes to the data outputs of the two controller ICs).

The touch SPI interface is selected when IC1 drives pin 17, T_CS-bar low while the LCD SPI interface is selected when IC1 drives pin 4, CS-bar low. Pin 5 will reset the LCD controller when brought high and is kept low for normal operation.

Pin 22 (D/C) is used to indicate to the LCD whether bits being sent represent data or a command. Pin 15 (T_IRQ) is used by the touch controller to send a signal to IC1 when the touchscreen is being used.

There are really only two differences between this circuitry and the Micromite LCD BackPack. Firstly, we have omitted the in-circuit serial programming (ICSP) header to save space.

This means you need to plug a preprogrammed Micromite chip into the board but it can still be configured and programmed through the CON3 serial interface.

The other change is that we have replaced the manual backlight control, which used a trimpot as a rheostat, with transistors Q19 and Q20. A PWM signal from output pin 18 of IC1 is used to control the backlight brightness. When pin 18 is driven high, it switches on NPN transistor Q20 which sinks current from the base of PNP transistor Q19, applying 5V to the backlight anode pin, pin 8 on CON4.

Q20's base is driven with approximately 26µA ([3.3V – 0.7V] ÷ 100kΩ). Given a typical beta of around 230 at that current level, it will sinks around 6mA from Q19's base, which is more than enough to drive it into saturation, given the typical 100-200mA drawn by the LCD backlight LED array.

Pin 18 is not a dedicated Micromite PWM output; we use a CFUNCTION in the software to provide an emulated PWM function at around 1kHz, to prevent backlight flicker without using too many of IC1's CPU cycles.

Next month

Next month we will show the final PCB design, the fully assembled unit, go over some of the details of the software, go through the PCB assembly, case preparation and final assembly procedures and explain how to use the unit. SC

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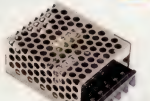

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LONG RANGE LoRa™ SHIELD

XC-4392

The Arduino® Compatible Long Range LoRa™ shield turns your Arduino® into a LoRa™ node capable of transmitting and receiving data over long distances. The perfect solution to your remote sensor and control projects.

- Compatible with 3.3V or 5V I/O Arduino Board.
- LoRa™ frequency Band: 915MHz
- Low power consumption
- Includes external Antenna (via I-Pex connector)

Radio transmitting devices must be used in accordance with Australian Communications & Media Authority guidelines www.acma.gov.au Due out early July

NEW 2017

$69.95

ARDUINO® COMPATIBLE RGB LED STRIP MODULE XC-4380

Strip of eight RGB LEDs which can be controlled by a single Arduino® pin. Up to 1000 LEDs can be daisy chained and run from one pin. 54mm x 10mm x 3.5mm

- 5V supply
- 256 brightness levels
- 500mA per module max

2017

$9.95

RELAY BOARDS

The easiest way to use your project to switch real world devices. Can switch up to 10A per channel.

- Status LEDs show channel status
- Screw terminals for easy connection to relay contact

1 WAY 5VDC XC-4419 **$5.45**
4 WAY 12VDC XC-4440 **$12.95**
8 WAY 12VDC XC-4418 **$19.95**

XC-4419

XC-4440

FROM **$5.45**

MAKE WITH PCDUINO & LINKER ACCESSORIES

PCDUINO V3.0 WITH WI-FI XC-4350

- Built in Wi-Fi capability
- Supported digital audio via I2C
- 121(L) x 65(W) x 15(H)mm

$89.95

VOLTAGE CONVERTER MODULE XC-4362

Marries 5V Arduino® shields with the 3.3V pcDuino to stop damage caused by connecting a 5V shield to pcDuino. 70(L) x 50(W) x 4(D)mm

$29.95

BLACK ENCLOSURE XC-4354

House your pcDuino in this enclosure for a safe and presentable appearance.

- Suits XC-4350

$19.95

PCDUINO 5MP CAMERA XC-4364

Connects directly to pcDuino V3.0, and captures an active array of video and images up to 2592 x 1944 resolution.

$19.95

SATA CABLE XC-4366

Connects your pcDuino V3.0 to a hard drive or SSD.

- 150mm long (approx.)

$4.95

7" LCD TOUCH SCREEN MONITOR XC-4356

- 1024 x 600 resolution
- LVDS screen with driver board
- 167(L) x 107(W) x 10(D)mm

$89.95

10% OFF THESE LINKER MODULES & SHIELDS FOR NERD PERKS CLUB MEMBERS

The Linker range is based around a series of Arduino® compatible modules, shields and cables. The Base Shield attaches to your pcDuino, Uno, Mega or Leonardo boards, and allows any of the Linker modules to be plugged in.

LINKER JUMPER LEADS

Connects Linker kit sensors/modules and Linker kit base shield. 2.54mm headers for easy and tidy connection. 4 pins, 2.54mm spaced.

- Sold individually

200MM XC-4558
500MM XC-4559
1000MM XC-4560

$4.95 ea

LINKER BASE SHIELD XC-4557

This is the base shield of Linker kit, it allows a connection between all Linker sensors/modules and Arduino®/pcDuino.

- Connections: 1 x SPI, 2 x IIC, 1 x UART
- 69(W) x 59(H) x 18(D)mm

$24.95

XC-4568

FROM **$4.95**

XC-4574

XC-4569

LINKER MOMENTARY PUSH BUTTON SWITCH	XC-4571 **$4.95**
DOUBLE BUTTON MODULE	XC-4573 **$4.95**
TILT MODULE	XC-4575 **$4.95**
BUZZER MODULE	XC-4580 **$5.95**
LIGHT SENSOR	XC-4574 **$5.95**
TEMPERATURE MODULE	XC-4576 **$6.95**
ROTARY POTENTIOMETER MODULE	XC-4578 **$6.95**
LED BAR	XC-4568 **$9.95**
TOUCH SENSOR	XC-4572 **$10.95**
4-DIGIT 7-SEGMENT MODULE	XC-4569 **$11.95**

SEE MORE AT www.jaycar.com.au/linker

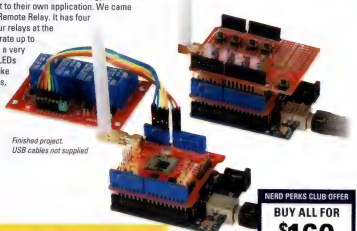
ARDUINO® PROJECT OF THE MONTH

LONG DISTANCE REMOTE RELAY

We were very excited to test just how far we could get a signal using new LoRa technology. With one test, we were able to get a signal to travel about 200m, including through the corrugated iron of the warehouse and the concrete office building. We then set about building a practical project to make best use of the technology, which our readers could easily adapt to their own application. We came up with this easy to build Remote Relay. It has four buttons at one end and four relays at the other end, so you can operate up to 4 devices remotely across a very long distance. It also has LEDs next to the buttons, so unlike other remote relay systems, there is feedback that the relays are operating as commanded. Brilliant!

DIY

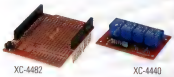
MORE INFO ONLINE



Finished project. USB cables not supplied

KIT VALUED AT $244

XC-4410 XC-4392



XC-4482 XC-4440

SP-0601 RR-0564 ZD-0250 WC-6028

NERD PERKS CLUB OFFER

BUY ALL FOR $169

SAVE $75

WHAT YOU WILL NEED:

2 X UNO MAIN BOARD	XC-4410	$29.95
2 X LORA SHIELD	XC-4392	$69.95
1 X FOUR CHANNEL RELAY MODULE	XC-4440	$12.95
1 X PROTOTYPING SHIELD	XC-4482	$15.95
4 X TACTILE PUSHBUTTON SWITCH	SP-0601	$0.95
1 X PACK OF 470 OHM RESISTORS	RR-0564	$0.55
4 X RED/GREEN BICOLOUR LEDS	ZD-0250	$1.25
1 X PLUG-SOCKET JUMPER LEAD SET	WC-6028	$5.95

SEE STEP-BY-STEP INSTRUCTIONS AT www.jaycar.com.au/lora-remote

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

BREADBOARD LAYOUT PROTOTYPING BOARDS

NEW 2017

FROM $4.95

NERD PERKS 2x POINTS

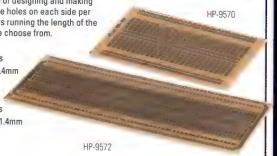
A fantastic way to transfer your concept breadboard design to PCB without having to go to the trouble of designing and making a PCB. Includes five holes on each side per row and power rails running the length of the board. Two sizes to choose from.

SMALL
- 25 rows, 400 holes
- 73mm x 47mm x 1.4mm

HP-9570 **$4.95**

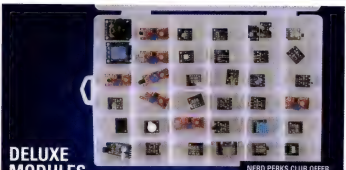
LARGE
- 59 rows, 862 holes
- 155mm x 58mm x 1.4mm

HP-9572 **$9.95**



HP-9570

HP-9572



DELUXE MODULES PACKAGE XC-4288

Includes commonly used sensors and modules for duinotech and Arduino® compatible projects. Comes with joystick, magnetic, temperature, IR, LED and more. 37 different sensors and modules.

NERD PERKS CLUB OFFER

$99

RRP $129

SAVE $30

$8.95 NERD PERKS 2x POINTS

0.25W CARBON FILM RESISTORS RR-1680

Includes five of virtually each value from 1 Ohm to 10 Meg. Sixty different values.
- 300 pieces

$12.95 NERD PERKS 2x POINTS

ATMEGA 328P IC WITH 16MHZ CRYSTAL ZZ-8727

Build your very own customised Arduino® compatible projects. Comes with the Arduino® Uno bootloader pre-installed and 16MHz crystal oscillator.

$13.50 NERD PERKS 2x POINTS

BREADBOARD JUMPER KIT PB-8850

Kit includes 70 stripped pieces of single core sturdy wire.
- 5 pieces each of 14 different lengths
- Supplied in a plastic box for easy storage

NS-3010

$15.95 88 NERD PERKS 2x POINTS

DURATECH SOLDER

60% Tin / 40% Lead. Resin cored.
0.71MM NS-3005
1.00MM NS-3010

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

1. 80W SUMLINE LAB POWER SUPPLY MP-3842
- Includes banana to alligator clamp leads
- Constant current and voltage options
- 0-16V/5A, 0-23V/3A, 0-36V/2.2A
- 53(W) x 300(D) x 138(H)mm

2. STAINLESS STEEL CUTTER & PLIERS SET TD-1812
- Set of five 115mm cutters and pliers
- Soft ergonomic grips

3. CAT III AUTORANGING DMM WITH TEMPERATURE QM-1323
- Compact, lightweight with rugged moulded case
- AC/DC 10A
- Data hold, capacitance, temperature
- Relative measurement
- 600V, 4000 count
- 137(H) x 65(W) x 35(D)mm

4. DESKTOP LED MAGNIFYING LAMP QM-3544 **WAS $64.95**
- 60 LEDS provide ample illumination, perfectly even light
- 3x and 12x magnifying lenses
- 350(H) x 180(Dia)mm

5. STORAGE CASE HB-6388 **WAS $39.95**
- For small instruments or test equipment
- Purge valves
- ABS construction
- 210 x 135 x 90

6. 70W ESD SAFE ANTI-STATIC SOLDERING STATION WITH LED DISPLAY TS-1440 **WAS $299**
- Precision Japanese manufactured with temperature stability and anti-static
- 230-240VAC supply voltage
- 65W capacity heater
- 200 - 480°C temperature range
- 0.5mm tip supplied

TECH TIP

DISTANCE TO SPOT RATIO EXPLAINED:

Distance to spot ratio is the ratio of the distance of the thermometer to the object being measured, and the diameter of the temperature measurement area. The larger the ratio number the better the resolution.

NON-CONTACT THERMOMETERS

Safely measure temperature in hard to reach places, hot or hazardous areas. Backlit LCD. Built-In Laser pointer.

8:1 SPOT QM-7215 **WAS $59.95**
NOW $49.95 SAVE $10
- 3 Digit
- 8:1 Distance to spot ratio
- Temp range: -30 to +260°C
- Auto data hold
- Carry case included

12:1 SPOT QM-7221 **WAS $139**
NOW $119 SAVE $20
- 3.5 Digit
- 12:1 Distance to spot ratio
- Temp range: -50 to +650°C
- Holster included

30:1 SPOT QM-7225 **WAS $249**
NOW $199 SAVE $50
- 4.5 Digit
- 30:1 Distance to spot ratio
- Temp range: -50 to 1000°C
- Carry case included

NOW $199

SAVE $40

VARIABLE LABORATORY AUTOTRANSFORMER (VARIAC)

MP-3086 **WAS $239**

Encased in heavy-duty steel housing, this unit enables the AC input to a mains powered appliance to be easily varied between 0 to full line voltage (or greater). A must for testing mains performance.

- 500 VA (fused) rated power handling
- 0–260 VAC @ 50Hz output voltage
- 185(D) x 120(W) x 160(H)mm

50VA 240VAC TO 115VAC STEPDOWN TRANSFORMER MF-1091

Includes overheat protection. When overheating , the thermal fuse will open, then close after unit cools down, restoring operation. Two pin US socket on unit for 110V appliance and cord plug for 240V power. Not for use in wet areas.

- This is not dielectrically isolated
- 50W

$49.95

20VA TOROIDAL TRANSFORMER

High efficiency, small size, & low electrically induced noise. Easy single bolt mounting.

- Outer/Inner 74mm / 21 x 30mm.

9V+9V 1.11A SERIES 2.22A PARALLEL MT-2082 **$29.95**

12V+12V 0.833A SERIES 1.66A PARALLEL MT-2084 **$24.95**

15V+15V 0.666A SERIES 1.333A PARALLEL MT-2086 **$24.95**

FROM $24.95

MULTI-TAPPED TRANSFORMERS

See website for specification.

15-30V, 30VA, 1A MM-2008

6-14V, 30VA, 2A MM-2004

$18.95 ea

POWER FOR THE WORKBENCH

Our range of highly efficient and reliable benchtop power supplies are specially selected to suit your unique testing and servicing applications. They use proven technology and are designed to give long service life in workshop situations. Features include low noise, low ripple and protection against overload and short circuit. Available in fixed or variable voltages. The most cost effective solution for your laboratory use, electronic and communications equipment maintenance.

FREE LED MAGNIFIER FOR NERD PERKS CARD HOLDERS

Valid with purchase of MP-3086, MP-3802 or MP-3087.

TH-1989 VALUED AT $44.95

$199 MP-3098

$199 MP-3802

$399 MP-3087

	MP-3098	MP-3802	MP-3087
Features	Fixed output voltage. Short circuit protection.	Compact size, high current and variable output.	Dual output. Operated independently. Digital voltage and current meters.
Output Voltage	13.8VDC	0-16VDC	2 x 0-32VDC
Output Current	20A	30A, 25A continuous	0-3A (x2)
Display	N/A	Analogue Meter (backlit)	LCD (backlit)
Size (W) x (D) x (H)	170 x 160 x 85mm	148 x 162 x 62mm	260 x 400 x 185mm

DESKTOP POWER SUPPLIES

Highly reliable desktop style single-output green adapters complying with the latest efficiency regulation (Energy efficiency level).

- No load power consumption <0.075W
- 90-264VAC input
- 60W/120W
- 12/24/48V

60W 12V 5A MP-3252 **$49.95**

60W 24V 2.5A MP-3254 **$49.95**

60W 48V 1.25A MP-3256 **$49.95**

120W 12V 8.5A MP-3258 **$99.95**

NEW 2017

FROM $49.95

IEC LEADS

- 1.8m
- Earthed
- SAA approved

STRAIGHT IEC FEMALE TO 240V PLUG PS-4106 **$8.95**

RIGHT ANGLE IEC FEMALE TO 240V PLUG PS-4107 **$9.95**

FROM $8.95

PS-4106

FROM 55¢

HEAVY DUTY POWER CABLES

PVC insulation. 250V wiring.

7.5A 24 X 0.2mm. WH-3040 - WH-3042

$0.55/m or $42/100m roll

10A 32 X 0.2 mm. WH-3050 - WH-3052

$0.80/m or $72/100m roll

FROM $1.25/m

AC MAINS CABLE

240V Power Flex fig.8 wire.

TWO CORE 7.5A WB-1560

$1.25/m or $99/100m roll

THREE CORE 10A WB-1562

$2.85/m or $229/100m roll

$4.15/m

HIGH CURRENT POWER CABLES

PVC insulation.

56A 8 gauge OFC.

RED WH-3060

BLACK WH-3062

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!

*Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY BY VISITING: www.jaycar.com.au/nerdperks

NERD PERKS CLUB MEMBERS RECEIVE:

10% OFF POWER CABLES*

*Applies only to cables listed above

POWER MANAGEMENT

CONTROL IT

These clever devices allow you to operate mains appliances using your Smartphone across Wi-Fi, and can also turn on and off appliances in hard to reach places. Applications include turning on lights to trick would-be burglars into thinking someone was home, or routinely turning on a cooler or heater. Choose between hardwired or plug-in models.

Common features:

- Freely available app for Android and Apple devices
- Scheduled timer (Routine operations)
- Countdown timer (Turns off after pre-set time period)

See website for full details.

PLUG-IN:

PLUG-IN WITHOUT POWER METER 240VAC 10A 2400W.
MS-6122 **$59.95**

PLUG-IN WITH POWER METER 240VAC 10A 2400W.
MS-6124 **$64.95**

HARD WIRED:

WI-FI WIRELESS SWITCH MODULE WITH APP
240VAC 7.5A 1800W, 1 year warranty. MS-6126

NSW CUSTOMERS: Unfortunately, these products are not available for sale in NSW.

MS-6122

FROM **$59.95**

MS-6126

$49.95

REMOTE CONTROLLED MAINS OUTLET CONTROLLER

Turn any standard mains outlet on/off via remote! Great for hard-to-reach power points. 30m range. Remote control up to 4 outlets.

- Mains outlet: 97(L) x 55(W) x 60(D)mm

1 OUTLET PACK
MS-6140 **$19.95**

3 OUTLET PACK
MS-6147 **$39.95**

FROM **$19.95**

TEST & MONITOR

SINGLE RCD (SAFETY SWITCH) OUTLET MS-4013

This RCD (residual current device) unit is designed to cut power within a second in the event of a fault condition, thereby preventing electrocution.

- Test function
- Reset button
- 10A 240V rated

$27.95

POWER POINT AND EARTH LEAKAGE TESTER QP-2004

Assess the safety of installed main sockets and earth voltages, and identify dangerous electrical installations.

- Rated current: 30mA +/-5%
- Rated voltage: 230VAC @ 50Hz
- Buzzer and three LEDs assist to quickly identifies issues
- IP65 rated enclosure

$34.95

MAINS POWER METER

MS-6115

Shows how much an appliance is costing to run and tracks the total power being used.

- 10A max rating

NOT AVAILABLE IN NSW

$21.95

REDUCE YOUR POWER BILL WITH LED LIGHTING

BRIGHT 12V LED STRIPLIGHTS WITH SWITCH

Encased in an attractive aluminium alloy, this pre-assembled LED strip features a generous beam angle with evenly distributed light. 12VDC powered.

280 LUMEN 313mm long.
ST-3930 **$24.95**

520 LUMEN 513mm long.
ST-3932 **$34.95**

FROM **$24.95**

50% OFF DIMMER FOR NERD PERKS CARD HOLDERS*
Valid with purchase of ST-3930 or ST-3932
ST-3938 VALUED AT $14.95

ULTRA BRIGHT IP67 WATERPROOF LED FLEXIBLE STRIP ZD-0575

Fully encapsulated, waterproof, perfect for any outdoor application. Daisy chain strips together for longer length. Ultra bright, 960 lumens. 12VDC.

$39.95

LOW COST 5M FLEXIBLE ADHESIVE LED STRIP LIGHTS

Can be cut to size and back with adhesive tape. Two colour temperatures available. 12VDC. 950 Lumens/metre.

COOL WHITE ZD-0575
WARM WHITE ZD-0577

$69.95 ea

240V IP65 180 LED LIGHT FIXTURE

ST-3945 **WAS $99.95**

Ideal replacement for traditional flourescent lights. Energy efficient and produces 2600 lumens. Weatherproof and dustproof. IP65 rated suitable for indoor and outdoor use. Comes with mounting bracket and a 1.8m length of lead with mains plug.

- 2600 lumen
- 30W power
- 675(L) x 135(W) x 93(D)mm

NOW **$79.95**
SAVE $20

MR11 LED REPLACEMENT LIGHT

High brightness MR11 LED globes commonly used for lighting caravan and marine interiors, desk lamps, and also used in retail shop ventilated display cabinets.

- 12VAC/DC, 2.2W
- 230 lumens

COOL WHITE
ZD-0650
WARM WHITE
ZD-0652

$14.95 ea

G4 LED REPLACEMENT LIGHT

An easy replacement for a G4 2-pin type halogen globe that uses significantly less power. Great for benchtop lighting, reading lamps, and a whole host of other applications.

- 12VAC/DC, 2.2W
- 230 lumens

COOL WHITE
ZD-0655
WARM WHITE
ZD-0657

$13.95 ea

TECH TIP

LOWER YOUR ENERGY COST THIS WINTER

The sun still shines bright through the short winter days, so you can still capitalise on free energy using solar. While the outside temperatures fall, if you're using electric heaters or air conditioning to keep your home warm, solar power can drastically reduce your energy bills. The best part is, you'll then be able to utilise the solar for summer-cooling when the mercury rises again too! Getting setup with solar is easy - read more online, or ask our friendly staff at your local store. They're knowledgeable and ready to help you.

FOR MORE DETAILS ABOUT LOW COST ENERGY VISIT: www.jaycar.com.au/save_with_solar

STEP 1: SELECT YOUR SOLAR PANEL

12V SEMI FLEXIBLE SOLAR PANELS

12VDC. Ideal for mounting to curved or other irregular surfaces such as an RV roof or boat.

15W ZM-9149 **$99.95**
30W ZM-9151 **$169**
80W ZM-9153 **$269**

FROM **$99.95** ZM-9153

12V MONOCRYSTALLINE SOLAR PANELS

Smaller, thinner, higher in efficiency and more affordable than our previous models, designed to withstand harsh environmental conditions.

- Aluminium frame
- Junction box included

5W ZM-9053 **$24.95**
10W ZM-9054 **$37.95**
20W ZM-9055 **$59.95**
40W ZM-9056 **$99.95**
80W ZM-9057 **$179**
120W ZM-9058 **$249**
150W ZM-9059 **$299**

FROM **$24.95**

SOLAR POWER METER QM-1592

NEW 2017

Find the optimum location for solar panels to get the best performance. Expressed as W/m² or BTU/ft².

- Includes carry case
- Range: 0-1999W/m² (634BTU/ft²)

$129

STEP 2: CONTROL

12V 8A WATER RESISTANT PWM SOLAR CHARGE CONTROLLER

MP-3720 **WAS $64.95**

Suits wet-cell and sealed lead-acid batteries. Pulse width modulation (PWM) for optimal 3-stage charging. Over current, over voltage, short circuit, over temperature and reverse polarity protections.

- 97(L) x 46(W) x 26(H)mm

Visit website for full specifications.

NOW **$54.95**
SAVE $10

SOLAR CHARGE CONTROLLERS WITH LCD DISPLAY MP-3129

Protect your valuable solar installation and maximise battery service life with our photovoltaic (PV) charge controller.

12V 20A MP-3129 **$179**
12V 30A MP-3722 **$219**

FROM **$179**

STEP 3: STORE

12V AGM DEEP CYCLE BATTERIES

Store large amounts of energy. Superior deep cycling performance for many different recreational and industrial applications such as camping, boats, motorhomes etc.

75AH 20KG WEIGHT SB-1680 **$249**
100AH 28KG WEIGHT SB-1682 **$299**

FROM **$249**

STEP 4: CONVERT

12VDC TO 230VAC PURE SINE WAVE INVERTERS

Designed to power large devices suitable for remote power applications.

- Over & under voltage protection
- USB port

200W MI-5726 **WAS $199 NOW $169 SAVE $30**
400W MI-5728 **WAS $249 NOW $219 SAVE $30**

FROM **$169**
SAVE $30

3.2V LIFEPO4 RECHARGEABLE BATTERIES

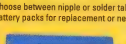
Lithium iron phosphate (LiFePO4) is a more chemically stable type of lithium rechargeable cell and becoming increasingly popular, due to increased safety and longer cycle life over traditional Li-ion cells.

FROM **$11.95**
NERD PERKS 2x POINTS

SB-2305

3.7V LI-ION RECHARGEABLE BATTERIES

Choose between nipple or solder tabs to make into battery packs for replacement or new projects.



FROM **$10.95**
NERD PERKS 2x POINTS

SB-2301

CIGARETTE LIGHTER ADAPTOR CABLE PP-1996

Power 12V devices from your car cigarette lighter socket. 1.8m long.

- LED power indicator
- Supplied with 8 DC plugs

$9.95

15A CIGARETTE SOCKET TO 8MM EYE TERMINAL

PT-4451

Power your 12VDC cigarette lighter plug devices from a range of 12VDC sources.

- 15A max.

$12.95

CIGARETTE LIGHTER 2 WAY SPLITTER WITH 2 USB PORTS

PP-2136

Power 2 12V accessories and 2 x USB devices at the same time. 12/24VDC.

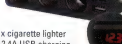
- Under-dash or panel mounting

$15.95

3 WAY CIGARETTE LIGHTER SOCKET WITH USB & VOLTMETER PP-2120

NEW 2017

Power up to 7 devices! 3 x cigarette lighter sockets, 2 x high-current 2.4A USB charging sockets, and 2 x standard 1A USB charging sockets. 12/24VDC.



$29.95

WHAT'S NEW?

PCB MOUNT PLUGS & SOCKETS

A new range of PC mount connectors to suit the latest USB & HDMI technologies.

NEW 2017

USB:

TYPE-A 3.0 MALE	PP-0923
TYPE-A 3.0 FEMALE	PS-0924
TYPE-A MICRO 3.0 MALE	PP-0925
TYPE-A MICRO 3.0 FEMALE	PS-0926
TYPE-B 3.0 FEMALE	PS-0928
TYPE-C 2.0/3.0/3.1 MALE	PP-0929
TYPE-C 3.1 FEMALE	PS-0930

HDMI:

TYPE-A MALE	PP-0941
TYPE-A FEMALE	PS-0942
MICRO FEMALE	PS-0946
MINI PLUG	PP-0943
MINI FEMALE	PS-0944

$3.95

DETACHABLE WALL PLATE DOUBLE ADAPTOR WITH 2 USB PORTS MS-4009

NEW 2017

Can be easily fixed to an existing power outlet without opening and rewiring.
2 x USB ports 5V, 3.1A (total).
- 230-240VAC,
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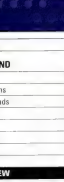

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 24 June - 23 July, 2017.

A new, high performance DSP BCL radio receiver . . . aimed squarely at AM listeners!

The Tecsun S-8800

Although it is a multiband receiver, covering shortwave (with SSB), long wave and FM (way down to 64MHz), it's the long-neglected AM radio listener that this new release from Tecsun Radios Australia is obviously aimed at.

When we say long-neglected, it's true: manufacturers seem to have gone out of their way to improve reception for FM listeners and even provided many more "bells and whistles" for short wave and even long wave enthusiasts. But to a large degree, AM reception has been much the same for many years.

And that's a pity, because despite what you might think, AM radio hasn't lost much (if any) of its popularity and many listeners, particularly in "the bush" have been crying out for a decent AM radio.

They might just have one with the Tecsun S-8800.

It's not a cheap set – with a recommended retail price of $349, you'd expect pretty good performance. Early tests in fringe AM listening areas (eg,

By Ross Tester

anywhere any distance from a transmitter!) suggest that the S-8800 is right up there, even exceeding many higher-priced sets in its ability to not only resolve distant stations but to maintain them at an enjoyable level.

OK, what does it offer?

The first thing you'll notice when you unpack the box is the infrared remote control. What's that? A radio with a remote control?

Unusual – but it's a bit of luxury for the user. All functions can be controlled via this remote so you don't have to get up from your favourite armchair to, for example, increase the volume! It will also allow you to turn the receiver on and off, change bands, scan (either memories or the band) and even let you enter frequencies directly via the keypad.

Another major departure from most receivers is the inclusion of rechargeable lithium-ion batteries, as distinct from the AA, C or even D cells most use. So you won't be forever buying new batteries – the two 18650 cells are Tecsun's own brand and are rated at 2000mAh, so should give you long listening! It draws around 75mA turned on (depending on volume, of course) or about 80uA when turned off.

Recharging is achieved by plugging in to any "USB" source (eg, a computer or a USB power supply [not included]) via a mini-D USB socket on the rear. The adaptor cable is included.

You can also run the radio from a 5V/300mA external DC adaptor – but be warned, most "switchmode" plugpack adaptors will introduce an intolerable amount of noise. If you can find one, choose a linear (ie transformer) supply – or simply charge the batteries regularly.

Incidentally, the infrared remote control uses standard "AAA" batteries, not some high-priced button cells.

We'll gloss over the longwave (LW) section of the receiver because there's not a great deal to listen to down there (unless you're into aircraft beacons. . .).

Longwave is used a lot more overseas, particularly Europe, and because of the characteristics of this band, you might be able to tune into some of those stations from time to time.

The shortwave (SW) and FM bands are much more interesting to Australian listeners, with a range of interesting stations on the shortwave bands including amateur operators (you'll find them around 1.8, 3.5, 7, 10, 14, 18, 21, 24 and 28MHz), older 27MHz CB radio (which often *isn't* worth listening to!) along with emergency, business and commercial users.

Finding them can be a bit of a "hit and miss" affair but once found, you do have the luxury of being able to store up to 650 stations in memory. The shortwave section covers just above the broadcast band (1.711MHz) through to almost 30MHz (actually 29.999MHz and with its single sideband plus AM reception, along with fine tuning, you'll be pulling in stations that you didn't know existed!

FM is quite different to what you might expect. As well as the FM

SPECIFICATIONS

FREQUENCY RANGES

FM: 87-108 / 87.5-108 / 76-108 / 64-108MHz (Tuning Step 0.01MHz /0.1MHz)
SW: 1711- 29999 kHz (Tuning Step: 1kHz / 5kHz)
MW: 522 -1620 kHz (with 1kHz / 9kHz tuning step)
520 -1710 kHz (with 1kHz / 10kHz tuning step)
LW: 100 - 519kHz (Tuning Step: 1kHz / 9kHz)

SENSITIVITY

FM (S / N = 30dB) <3μV
MW (S / N = 26dB) <3mV / m
LW (S / N = 26dB) <5mV / m
SW (S / N = 26dB) <20μV
SSB (S / N = 10dB) <3μV

SELECTIVITY (Factory default of AM IF bandwidth is Narrow Band):

FM: >35 dB (± 200kHz)
MW / LW: >40 dB (± 9kHz)
SW: >40 dB (± 5kHz)

S/N RATIO

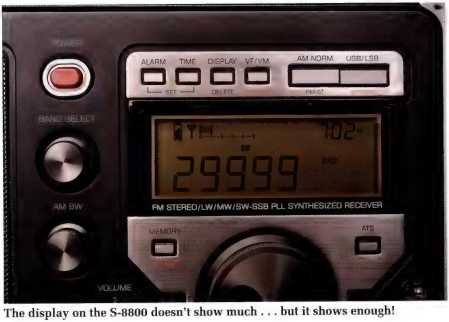
FM: >5dB
MW/LW: >40dB
SW: >45dB

IFs

SSB, AM: 1st IF: 55.845MHz 2nd IF: 10.7 kHz
FM: 10.7MHz

FM STEREO CROSSTALK: >35 dB

OUTPUT POWER (distortion 10%): ≥450mW



The display on the S-8800 doesn't show much . . . but it shows enough!

Rear and side views show there aren't a huge number of controls – most of the work is done by the receiver itself. On the back you have connectors for antennas and a mini-USB charging socket, while the side has switches for internal and external antennas, DX and local reception plus stereo (on FM) headphone socket and line outs.

broadcast band (88-108MHz) you can also tune in as low as 64MHz. In this 64-88MHz "slot" there's quite a lot of two-way radio used by all sorts of businesses and organisations.

Both the FM and SW bands can be significantly enhanced by the connection of an external antenna; provision is made for this on the back panel via a BNC socket.

AM reception

As we noted at the start of this review, AM (amplitude modulation) is where the Tecsun really shines. There are two major features required of a good AM receiver – excellent sensitivity and excellent selectivity. The first mainly refers to the radio's ability to pick up very weak stations. Selectivity refers to the radio's ability to differentiate those weak signals from those (perhaps stronger) on adjacent channels.

Another important characteristic is frequency stability – it's one thing tuning in that elusive, faint station – the last thing you want is the receiver "drifting" so you lose it.

Overlaying all this is the fact that the Tecsun offers Digital Signal Processing on the HF band so you virtually have the power of a computer to help you enjoy listening.

In deep fringe areas, far outside the "normal" range of AM radio stations, the P-8800 consistently outperforms other receivers, even those costing considerably more.

One feature which long-distance (or "DX") listeners will enjoy is the AM bandwidth switching. When an AM signal is noisy, being able to adjust the bandwidth from 6kHz down to 3kHz, or even 2.3kHz, can mean the difference between annoying noise and an intelligible signal. Reduced bandwidth does have a cost, of course, and that is reduced fidelity. But if there's a choice between receiving a station or not, it doesn't really matter!

You also have the choice of channel spacing. Here in Australia, AM stations are 9kHz apart, so that is where you'd normally have the switch set. But if you're listening to some overseas DX, you might want to change to 10kHz spacing. This has another benefit: you'll extend the normal range of 520-1620kHz up to 520-1710kHz. You can step through the dial in 1kHz steps, if you wish.

Like the FM and SW bands, the AM band can be rather siginificantly enhanced by connection of an external antenna (again, connections on the back). The difference is that the AM external antenna input is high impedance, so a "long wire" antenna is ideal. While (theoretically) an AM antenna should reflect the frequency you want to listen to, there's an old bushie rule of thumb: as high and as long as you can make it!

If you do get into trouble with too much signal (maybe from a local radio station), there is a local/DX switch to attenuate it.

While we're talking about sound quality, the Tecsun S-8800 offers 2W of audio output, driving a relatively large – for a radio – speaker (40mm). You won't suffer for lack of volume – and there are bass and treble controls to tailor the sound the way you want it. And remember, all these functions are available on the remote control.

One thing we haven't mentioned is its size. It's no hand-held, at 192(W) x 113(H) x 33mm (D), and weighs just over half a kilogram without batteries. And we almost forgot – the Tecsun also sports a clock with various alarm functions on its large, easy-to-read LCD display.

So there it is: a great performer on LW (for what it's worth), SW and an extended FM band. But an outstanding performer on AM with a range of user controls and functions to make listening a pleasure, rather than a chore.

If you live in, or go "bush" and want a radio that will let you keep listening where other radios have given up, or if you're a city resident who wants to give DX listening a go, try the Tecsun S-8800.

Where from:

Tecsun Radios Australia
Unit 24, 9 Powells Road,
Brookvale, NSW 2100
www.tecsunradios.com.au SC

"Over-The-Top" rail-to-rail op amps

by Nicholas Vinen

In our Deluxe Touchscreen eFuse project this month, we're using two "Over-The-Top" rail-to-rail op amps which provide functions available in few other op amps. Made by Linear Technology (now part of Analog Devices), they are very useful in instrumentation applications.

Op amps are one of the most common types of IC. We estimate that there are close to 10,000 different types available; if you discard those which are related (single/dual/quad versions, for example) there are still more than 1000 distinct designs.

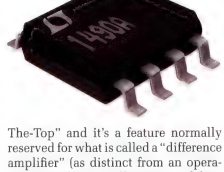
So it's unusual to have design criteria so strict that you are only left with one or two suitable types.

The combination of attributes which make these "Over-The-Top" op amps useful in the eFuse would also make them valuable in other instrumentation roles.

The particular op amps have the following type codes: LT1490A/LT1491A and LT1638/LT1639, representing dual and quad versions respectively. The major difference between the two pairs is the trade-off between bandwidth, noise and power consumption.

One of their unusual features is the fact that both the differential and common mode input range is 44V, regardless of the op amp's supply voltage. So you could use these op amps to measure the voltage across a shunt that is supplying the high side of a motor running off 36V DC, even if your op amps are only running off a 3V supply.

That's why they're called "Over-The-Top" and it's a feature normally reserved for what is called a "difference amplifier" (as distinct from an operational amplifier). Difference amplifiers are similar to instrumentation amplifiers but they lack input buffering, having an internal precision divider between each input and an internal instrumental amplifier. One example is the INA117 from Texas Instruments.



So difference amplifiers are capable of handling very high input voltages and tend to have very good common mode rejection ratios (CMRR), in order to allow them to accurately measure small differences between those input voltages. However, they are quite restricted in their applications, as they often have fixed gain and the higher the allowable input voltage, the higher the gain tends to be.

While the LT1490/1490/1638/1639 can't handle particularly high voltages, they do have much more flexibility than a difference amplifier, providing traditional op amp functions, along with a much higher input impedance for more accurate measurements.

Other notable features

While the Over-The-Top feature is interesting, that isn't actually why we chose these devices for the eFuse.

The main reason is their combination of a very wide operating supply voltage range, from 2V to 44V (!) along with rail-to-rail inputs and outputs, with an output which can swing close to each rail (maximum 10mV) and a low typical input offset voltage of ±110µV (maximum ±800µV from -40°C to +85°C).

Two of the biggest drawbacks of traditional rail-to-rail op amps are their limited supply voltage range (usually 2.7-16V; the LMC6482 we often use has a rating of 3-15.5V) and the fact that the output voltage will only swing close to either supply rail, but not actually reach it.

While it's impossible for an op amp output to actually reach either of its supply rails, the op amps described here can get very close, typically to within about 3mV of the negative rail when lightly loaded, as you can see from

Specifications (typical figures)	LT1490A/LT1491A	LT1638/LT1639
Supply voltage range (Vs)	2.4-44V	2.4-44V
Quiescent current	40µA/amplifier	170µA/amplifier
Gain bandwidth product	200kHz	1.2MHz
Slew rate	60mV/µs	380mV/µs
Input offset voltage	150µV (250µV for LT1491A)	250µV (350µV for LT1639)
Input bias current	1nA	20nA
Input noise voltage	50nV/√(Hz)	20nV/√(Hz)
Large signal voltage gain	1500V/mV @ Vs=3-5V, 250V/mV @ Vs=30V	1500V/mV @ Vs=3-5V, 500V/mV @ Vs=30V
Output swing, no load	3mV to Vs-12mV	3mV to Vs-20mV
Output swing @ 5mA	250mV to Vs-600mV	250mV to Vs-600mV
Output short circuit current	+15, -30mA (Vs=3V), +25, -30mA (Vs=5V)	+15, -25mA (Vs=3V), +20, -25mV (Vs=5V)
PSRR	98dB	100dB
CMRR @ 1kHz	92dB	103dB

Fig.1. By comparison, the LMC6482's output saturation voltage is similar when sinking 100µA+ but only drops down to around 10mA when sinking just 1µA.

While the LM358 isn't a rail-to-rail op amp, it is designed for operation from single supplies and was one of the earliest designs to have an output swing that came close to the negative rail. It's still in common use but it too struggles to deliver an output voltage below 10mV.

Power supply, bandwidth and noise

The LT1490/1491 have a low power consumption figure of just 40µA/amplifier and 170µA/amplifier for the LT1638/1639. The trade-off in achieving this is in the bandwidth and noise figures. The LT1490/1491 have a gain bandwidth (GBW) product of just 200kHz while the LT1638/1639 have a GBW of 1.075MHz. Noise figures are 50nV/√(Hz) for the LT1490/1491 and 20nV/√(Hz) for the LT1638/1639.

But for instrumentation purposes like our eFuse, those figures are more than adequate. A bandwidth of say 50kHz (ie, with an effective gain of four) still results in a 0.1% settling time of around 20µs. So if you are feeding the op amp output to an analog-to-digital converter (ADC) in a microcontroller, unless you're sampling above 50kHz, it could be an advantage as it will act as a low-pass filter to reduce aliasing in the ADC.

Another unusual feature of the op amps described here is that they will tolerate a reverse supply condition (ie, V+ below V-) with less than 1nA of current flow for reverse voltages up to 18V. So they could be used in battery-powered applications and powered directly off the battery without concern for damage if it were to be accidentally reversed. No damage will occur with input voltages down to -2V.

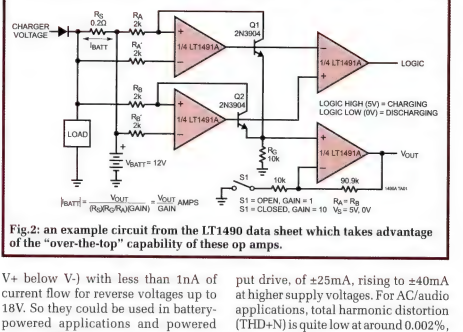


Fig.2: an example circuit from the LT1490 data sheet which takes advantage of the "over-the-top" capability of these op amps.

And they will tolerate up to 18V on all input and output pins in the absence of supply voltage, allowing them to be "shut down" by switching V+ off using a transistor. They will also tolerate driving a capacitive load of up to 200pF, with no extra compensation, or up to 10nF (LT1490/1) or 1nF (LT1638/9) with an added Zobel network at the output.

High open-loop gain (1.5 million times) and CMRR (98dB), along with phase reversal protection, makes these op amps suitable for precision DC work. They also have a reasonably strong output drive, of ±25mA, rising to ±40mA at higher supply voltages. For AC/audio applications, total harmonic distortion (THD+N) is quite low at around 0.002%, limited mainly by noise.

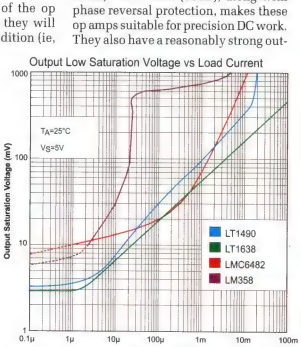


Fig.1: a plot of the typical output voltage of four different op amps when fully to the negative rail versus load current. The LT1490/1638 op amps go lower than most other high-voltage-capable rail-to-rail op amps. Note that to take advantage of this, the op amp output must be very lightly loaded.

Conclusion

These op amps are excellent general purpose devices and come about as close to an "ideal op amp" as we've seen. They have little change in performance over a wide range of supply voltages and their high maximum supply voltage makes them very useful in circuits with multiple supply rails.

It also means that they will be useful in a variety of situations, whether you're building a circuit which runs off a single Li-ion cell, a 12V power supply or with substantially higher voltage rails.

We expect we will use this family of op amps in more projects in future. They are available from Digi-Key (DK) and element14 (e14), with catalog codes as follows:

LT1490ACN (dual, 200kHz, DIP) – DK *LT1490ACN#PBF-ND*; e14 *9560530*

LT1490ACS (dual, 200kHz, SOIC) – DK *LT1490ACS8#PBF-ND*; e14 *1663433*

LT1491ACN (quad, 200kHz, DIP) – DK *LT1491ACN#PBF-ND*; e14 *9560556*

LT1491ACS (quad, 200kHz, SOIC) – DK *LT1491ACS#PBF-ND*; e14 *1330667*

LT1638CN (dual, 1.2MHz, DIP) – DK *LT1638CN8#PBF-ND*

LT1638CS (dual, 1.2MHz, SOIC) – DK *LT1638CS8#PBF-ND*; e14 *1663461*

LT1639CN (quad, 1.2MHz, DIP) – DK *LT1639CN#PBF-ND*

LT1639CS (quad, 1.2MHz, SOIC) – DK *LT1639CS8#PBF-ND*; e14 *1330682*

SC

SERVICEMAN'S LOG

Perished belts stop a cassette deck

Dave Thompson*

Thirty years ago, virtually everyone had one or more cassette players or decks and cassettes were the favoured music source when you were on the move. But few are used now, so much so that I thought a recent request to fix a dual cassete deck was a joke.

A few weeks ago, another April Fool's day slipped past almost unnoticed, as is typical for me. In fact, I don't really get into the spirit of Halloween, Valentine's Day and other similar "celebrations".

I suppose I'm being cynical but to me they seem to be just another opportunity for marketing people to exploit an occasion for commercial gain.

When I was growing up, nobody I knew ever gave Halloween a second thought, other than perhaps to acknowledge it as an ancient, vaguely religious date on the theological calendar, celebrated overseas, mainly by Americans.

Yet in recent years, the creeping Americanisation of our society has resulted in costumed "Trick or Treaters" going from house to house begging for lollies while in the weeks before, retail chain stores hawked cheap, Halloween-themed merchandise hoping to cash in.

Kids probably have no idea what it even means. Give it a few years and we'll probably be celebrating Thanksgiving...

I can recall two rather excellent technology-related April Fool's gags that at the time made quite an impact. The first was in the mid-nineties when PlayStation gaming was new and all the rage; one of the biggest games at the time was called Tomb Raider. I was one of many who bought the game and it was worth every penny.

It was also ground-breaking in graphics, in-game physics and for introducing Lara Croft, the main character.

This stirred up a lot of controversy in the increasingly politically-correct landscape of the times. On the one hand, it was commendable to have a female heroine, instead of some muscle-packed, wise-cracking, cigar-chomping meathead like Duke Nukem and his mates.

Yet on the other, she was created with some rather unrealistically-proportioned, um, attributes, raising the hackles of feminists everywhere. Despite the backlash, the game sold millions of copies and the franchise went on to rake in gazillions of dollars for everyone involved.

At the height of this fervour, one of the bigger technology magazines of the day published an article revealing a supposed "Easter egg" that players could activate within the game by tapping their PlayStation controller buttons in a certain sequence, in time with a Spice Girls hit song of the day.

If they got it right, players could complete the rest of the game with Lara Croft naked! Nowadays, this might seem a little lame but back then, it was **huge** news as rumours had followed the game since it was released about a supposed "nude patch" built in by the developers.

However, players soon discovered that no matter how hard they tried, I couldn't get the hack to work. Er, I mean, **they** couldn't get it to work. I'll bet a lot of controllers were worn out trying, but it was all an elaborate April Fool's joke on the part of the magazine and it certainly fooled a lot of people.

In a similar vein, around the late nineties, a technology web-site published a story on how to defeat the hard-wired frequency lock on a particular model of the latest Intel processor, thus allowing it to be overclocked.

The back story to this is quite interesting; the then-new Celeron and Pentium range of processors from Intel sold like hot-cakes because previous versions of these CPUs had been an overclocker's dream, with some users running the Celeron versions hundreds of megahertz faster than they were designed and rated for, just by upping the frequency multiplier on their motherboards.

Until this was discovered, overclocking any CPU usually resulted in an extremely unstable system and in most cases just wasn't worth the effort. However, experimenters soon discovered the Celeron processor, as long as it was kept cool, could be thrashed mercilessly and would remain stable and very usable at ridiculous speeds.

These supposedly lower-end processors cost far less than the Pentium equivalent, yet over-clocked Celerons were out-performing their pricier Pentium cousins, something Intel hadn't considered and certainly didn't approve of, and were soon designing ways to stop people doing it once and for all.

To prevent buyers getting more for less, the following generation of Intel processors featured a bus lock that prevented users over-clocking them by the usual means. This meant that you couldn't increase the clock fre-

Items Covered This Month

- Panasonic RX-FT570 dual cassette deck repair
- Currawong amplifier repair
- Sometimes a drill repair isn't always best

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

~PLAYERS SOON DISCOVERED NO MATTER HOW HARD THEY TRIED, I COULDN'T GET THE HACK TO WORK...

quency and run the chip faster – well, you could, but the processor wouldn't take any notice and would simply chug along at its rated speed.

That is, until a respected technology-related website published a 'how-to' on how to defeat this locking system. Apparently, owners could physically disable the lock by drilling a tiny hole into their chip at a very precise location, the process of which was clearly detailed in the article.

And of course, many overclockers raced out to their workshops and got their electric drill and proceeded to drill this hole in their CPU, failing to notice the publication date of the story; April 1st. It was all an April Fool's gag and one the publishers considered so obviously fake and so patently ridiculous that nobody in their right mind would actually go ahead and do it.

Sadly, they underestimated their audience and had to quickly upload a retraction and apology in the hope that it would stop the wholesale slaughter of thousands of Celeron processors. It was an excellent prank; unless you were fooled by it!

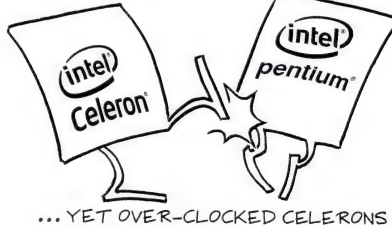
I mention all this because on April 1st last, I got a call from a guy asking me if I sold cassette tape players or more specifically, a portable cassette player with two tape decks so he could do tape-to-tape dubs. This caller happened to sound very much like a friend of mine who is well known for his prank phone calls, such as calling and claiming to be from Inland Revenue, or the police etc.

He's gotten me a few times over the years and given this current caller's slightly odd vocal syntax was very similar to my friend's, I congratulated him on his inventiveness but informed him I'd busted him this time.

Embarrassingly, it was a real customer with a real request and I had to eat a big piece of humble pie and apologised profusely. Once I'd explained my April Fool's supposition, we had a bit of a laugh and got down to business.

He explained that he was a choirmaster and his method of teaching the choir-members' separate vocal parts was to record his part onto a cassette tape using his trusty portable Panasonic RX-FT570 tape recorder. He'd then make several copies using the twin tape decks and pass the tapes out to other members to be learned.

Hmmm, I still wasn't sure this wasn't my prankster friend, riding out the gag for as long as he could. The caller further explained he'd used this system for the last 20 years and it



... YET OVER-CLOCKED CELERONS WERE OUT-PERFORMING THEIR PRICIER PENTIUM COUSINS

had worked perfectly until the previous day, when he had gone to record something and discovered the tape no longer turned in the drive.

He remarked that he could still hear the motors whirring away inside the unit, but the tape was no longer moving in either deck. He suspected it was time to throw it into the skip and buy another one, hence his calling around the different companies in the phone book.

By the sounds of it, he was not having much success. By now I was convinced this was a serious request and being relatively up-to-date with all this modern digital recording stuff, I politely suggested that perhaps he would consider modernising? Instead of tapes, people these days were using digital voice recorders, and this might be the answer.

He responded with a very resounding: "No!" He told me he was "old-school", didn't own a computer and had no interest nor idea how any of this new-fangled stuff worked. I had to be honest and tell him that I imagined the only suitable cassette players around now would be second-hand from the auction sites, as I knew of nobody selling them new.

Thinking the best way forward might be to repair his old one, I asked him a few more questions about what his recorder was doing when he pushed the play button or tried rewinding and so on. He repeated that when he pushed any of the buttons, he heard noises from within but the tape didn't roll.

He'd tried several tapes so it wasn't a jammed cassette and the radio and speaker side of things still worked as normal. I told him that it sounded to me like a belt, capstan, tension wheel or something similar had come adrift in the transport mechanism, but given the thing was almost half as old as I am, it wasn't all that surprising.

He was under the impression that because the recorder had seen so much use over the years, it was likely time for a new one anyway. However, being a Panasonic, I knew it would have good hardware in it and suggested it wouldn't hurt for me to at least take a look at it before he junked it, as it might be repairable.

He confessed he hadn't even thought about that option and became quite animated knowing that I might be able to fix it. I warned that he shouldn't get too excited until I had a look and arranged for him to bring it around to the workshop the following day.

When he arrived, he was a lot older than I'd pictured by his voice, which explained why he was not overly interested in adopting more modern technology. I did mention briefly the possibilities of digital recorders and pointed out there were cassette to digital converters available these days but he was convinced it would be too complicated.

I happened to have a digital voice recorder I'd constructed a few years before and dragged that out to show him. And while he seemed quite impressed by it, he made the comment that as all his colleagues were much like him with regards to modern technology and would likely have trouble getting to grips with using something like this; perhaps it would be best to stick with their tried-and-true method.

And that was fine by me; it worked for them well in the past so now all I had to do was try and get this thing working. I assured him I would try my best.

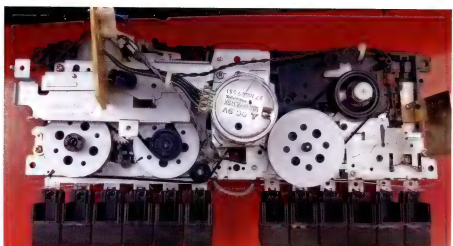
Anyone who has had a tape deck of any description apart before will tell you that they are complicated devices. The concept is simple enough: a motor drives a rotating shaft which turns a spool (the capstan) inside the cassette, causing the audio tape to be dragged past the record or playback head at a certain speed.

The magnetic information on the tape is read by the head and passed on to the pre and main amplification system, whether it is an internal amp as in this portable device or an external amp as in a home stereo system.

However, the mechanism to do this is anything but simple. A typical cassette player usually contains a transport mechanism module and this can be unbolted and replaced as a whole if required, or sometimes individual parts can be replaced if they wear out.

In this particular unit, there are two such modules, sitting side-by-side and each individually operated by its own set of buttons but driven by the same motor and belts arrangement. The core of any such system comprises the various rubber drive belts that turn the different spools, gears, capstans and wheels.

IN THE OLD DAYS, ONE COULD SIMPLY GO DOWN TO THE LOCAL SUPPLIER & GRAB A REPLACEMENT BELT



This view of the Panasonic's RX-FT570 dual-cassette transport mechanism shows some of the belts. All of the belts had perished or cracked.

Considering these tape systems were designed in the days before computers, they really are a feat of engineering and design. Each of the two systems consist of dozens, if not hundreds, of tiny springs, levers, cogs, bearings, gears and pulleys, all designed to move the tape at a constant speed over the playback and record heads.

If the speed was to change, the resulting distortion, including wow and flutter, would be immediately noticeable, so it is vital that the tape speed remains absolutely constant, and at the exact speed required.

It wouldn't be so bad if the tapes to be played were recorded only on this machine, as then it wouldn't matter what speed the tape travelled at, as long as it was the same for record and playback, but pre-recorded tapes could also be played and so the playback speed must match a standard recording speed. When belts start to stretch and slip, the speed changes and problems arise.

In the old days, one would simply go down to the local supplier and grab a replacement belt; you'd tell the bloke behind the counter what player you had and he would go and pick out the required belts and you'd be on your way.

Of course, those days are long gone; one, you'd be hard-pressed to find anyone selling one belt, let alone a range, and two, shop-keepers with that kind of product knowledge died with the corner grocer.

Opening the player was simplicity itself; none of these silly, so-called security screws, just plain old Philips-head PKs. Six held the case together, with one cleverly hidden under the folding handle to reinforce the top section and once removed, the case split apart.

Demonstrating the class and quality of this era of manufacturing were the plugs and sockets connecting speakers, antenna and battery compartment; once the plugs were separated, the front of the case came away completely, revealing the two transport mechanisms in all their glory.

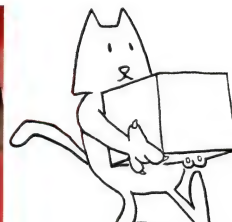
I could see straight away that one of the belts was lying askew and after removing a couple of retaining screws and turning the entire tape-playing section over, I could see another, smaller belt also off its tracks.

I was actually happy to see this, even though I knew it unlikely I had the correct-sized belts in my bits-boxes, as it meant that replacing them would likely get this thing up and running again. It could just as well have been any one of the multitudes of tiny coil springs, leaf-springs, actuators, trunnions, levers, mechanical sensors or other impossible-to-replace parts that had worn out, fallen off or failed instead.

A closer inspection revealed that all of the belts were in a pretty sorry state, with minute cracking and perishing obvious under the magnifying glass, so I decided to replace them all.

As is becoming the norm these days, I hit AliExpress and there was a belt kit containing 30-odd different-sized belts, all for a couple of bucks shipped to my door. I promptly ordered the kit.

The only worry was disassembling the motor and transport assembly enough to get the old belts out and the new ones in, and this is where lots of photos and parts location awareness pays off as every screw is specific to its location and purpose, and mixing them up can result in no or limited movement.



It's always tricky when there is a week or more between pulling something apart and reassembly, so those photos and even a screw map can really help. Once the kit arrived, the belts were changed and the player reassembled as per my references and the customer happy as Larry. Job done.

Blaming an old lady for an amplifier mishap

P. C., of Woodcroft, SA, blamed his 80-year old Mum for his inadvertent ham-fistedness when testing an amplifier. This is unchivalrous to say the least but it does emphasise how you need to concentrate when making high voltage measurements in a piece of electronic equipment.

In this case it was the SILICON CHIP Currawong 20W/channel valve amplifier that I had enjoyed assembling. I had been umming and ahhing for the past six months or so as to whether to build the Currawong amplifier. It interested me from the moment it was published back in 2014.

After all, I had only finished the 20W Class-A amplifier and two sets of Senator speakers towards the end of 2016. But the idea kept nagging at me so I proceeded to order the PCB, front and rear panels as well as the top Perspex cover. After all, you only live once and if I didn't do it now I probably never would.

After a while the parts started to arrive and as they did I spent an enjoyable time in the shed workshop assembling the PCB. The transformer was the last to arrive and while waiting for it,

time was spent building, sanding and painting the plinth. Then it was time to begin the final assembly.

It all went together quite quickly and the initial testing went very well although I was a little concerned that the HT at the cathode was measuring 375VDC whereas the value on the circuit is 310VDC. I had almost 14VAC on the 12.6V heater supply for the 12AX7s also.

I then wondered what my mains supply voltage was... good grief – nearly 256VAC! So much for Australia's official mains voltage being 230VAC. We have recently had an underground mains cable upgrade and a new transformer fitted across the road.

Apart from that, all the test procedures went to plan. The power LED started out red and after about 20 seconds went green and I had HT; time to plug in the valves. I chose the EH6L6 matched quads and the EH 12AX7s as they seemed a good compromise between performance and price. I fitted 10Ω, 5W resistors across the speaker terminals as dummy loads.

It was now time for my final voltage checks. I was concentrating hard on not shorting anything and keeping in mind the high voltages present. I had the negative meter probe on the metal valve base and the other poised over the cathode of D1 ready to lightly touch it when, out the blue came "Yoo Hoo, Peter" in a loud, shrill voice that could only be my Mother.

It scared the living daylights out of me! Almost simultaneously, there was a loud thwack sound and I now had two very black and violently blown fuses, F1 and F2.

This could not be good. There was just an eerie silence followed by the request to join my Mum and wife for coffee and cake. Talk about **bad** timing! I thought about it, decided it might be time for a break and complied. I held my tongue and did not mention the chaos Mum had caused but just enjoyed the coffee.

After about an hour I came back to the workshop for a post mortem. I worked out that as I jumped when she called out to me, I managed to short the cathode of D1 to the load end of F1, effectively shorting the 470μF, 400V capacitor. No wonder there was quite a loud thwack.

From here I though it might be a good idea to test it in two steps; the HT section first followed by the LT/control section. My first move here was to check D1 & D2 – both OK. At this point I removed the plug from CON8, leaving CON7 in place, fitted a new 1A slow-blow fuse and gingerly switched on.

I was greeted by the four blue LEDs near the output transformers, glowing brightly. The HT measured 275VDC once more. No more problems here, so it was onto the LT/control section.

After the LEDs faded down to nothing, I removed the plug from CON7 and refitted the plug to CON8. Doing this meant I could work the rest of the circuit without fear of getting zapped from the HT supply.

Before applying power I did a quick probe around with my ohmmeter, looking for obvious shorts – I found nothing so I turned it off, fitted a new 3A slow blow F2, switched it on again and that blew the fuse again. Oh, Bother! It was time to have a closer look at the circuit diagram of the LT power supply.

I then noticed CON9 which does not seem to be used or fitted on the PCB. It does have plated-through pads on top of the board which could be handy for me to apply 12V DC from a current regulated bench power supply.

I removed the CON8 plug for total isolation, applied 12V DC to pin 1 of CON9 (+) and the negative to the metal frame of an octal valve base, set the maximum current at 800mA and switched on.

The current shot up to this maximum and I noticed that the headphone relays were switching in and out before the current limit kicked in. Weird!

At this point, I also got the very faint whiff of burning smell. Putting two and two together, I suspected transistor Q9 and this felt quite hot to the touch. I de-soldered it and tests revealed it had gone faulty, measuring about 15Ω leg to leg.

I soldered a new one in its place and retested in the same configuration. This time everything went OK. The power LED would come on red and turn to green after 20 seconds and I had the correct supply on pins 1 & 7 of the 4093B IC. I then reconnected the plug into CON8, fitted a new 3A fuse and switched on to be greeted by... nothingness!

My previous tests had proven there was nothing wrong with REG1 or any other component; which left only the W04 rectifier. Reluctantly, I de-soldered BR1 and tests showed it to have failed open-circuit, which is a blessing because if it had failed short-circuit who knows how much more damage might have been done?

I did not have another in my parts store but at this point it was only about mid-afternoon on a Saturday so my local would still be open. It took only half an hour to get there and back and fitting took a few minutes at most. After I refitted everything I switched it on and everything went smoothly from there.

I set the amplifier up on the kitchen table feeding an old set of surround sound speakers that I use for this sort of thing, connected my venerable Marantz CD74 CD player and was greeted by sweet and clear valve-amplified music.

The total parts count of this mishap only came to one transistor and a small bridge rectifier plus four fuses,

BLAMING AN OLD LADY...

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so it was not a big issue and the time from when I heard those first startling words "Yoo Hoo, Peter" to the time it was all up and running again was only a matter of a couple of hours.

It should never have happened in the first place but I kept the workshop door open that day because it was warm and I needed the airflow in the shed. Mum doesn't know anything about it!

In summary, it certainly was an interesting build. I chose to upgrade the carbon resistors to metal film in the hope it might help value drift in the longer term as in the old days carbon resistors used to drift high. There was quite a wait on the two 470µF, 400V capacitors, as well as the transformer.

The valves I ordered from a company called Evatco and they arrived next day. I was rather shocked at the prices of some valves. It would have been easy to spend up to $550-600 on the valves alone. This makes me a bit annoyed when, as a teenager in the mid-1970s, I had collected a huge shipping trunk full of the things and a shed load of old radio and TV chassis that I used to muck about with.

Then my father decided it was **his** shed after all and he wanted it back; he made me load it all into a trailer and carted it to the local tip. We did not really get on that well after that.

When a repair isn't the best option

A. F., of Kingscliff, NSW got a reward recently for looking at a damaged electric drill and he didn't do any repair work at all.

When I read Dave Thompson's Story about a brand new nail gun that failed after a short period of use, it reminded me of a brand new electric drill that I purchased a short while ago which failed. It eventually resulted in me receiving the most unexpected and highly rewarding gift, and I did not even have to do any repair work!

This saga started when a young family member named Ron asked if he could borrow my electric drill, to install some shelves in the garage of his new home. I was reluctant to lend him this old tool, as I had used it a lot during my renovations to my first home, when I was struggling to pay off my loan and also afford the renovation costs and tools.

I explained to Ron that my drill had to be used gently, due to its age. When I used it, if the body of the drill became warm, I knew that it was time to go for a coffee break.

The drill was an old two-speed model with a two-stage trigger. When the trigger was first pulled, the circuit routed the power to the brushed armature through a single power diode, which resulted in a half-wave DC being applied to the armature, resulting in a slower RPM at the chuck of the drill.

Pulling the trigger all the way resulted in the diode being shorted out and full wave 230VAC being applied to the armature and field coil, and a higher RPM; simple but effective.

Ron disappeared with my drill, and it was several days later that he showed up, with an unhappy look on his face, like a puppy that knows it has been naughty. He explained that my drill had stopped working.

One sniff at the ventilation slots of the drill and I knew from the pungent smell of burnt varnish that he had cooked the windings on my old drill. Ron quickly explained that he would replace my drill with a new one, if I would use my knowledge of power tools to buy myself a new suitable drill, and buy a second one for him.

I went off to Bunnings Warehouse, and found an Ozito brand domestic quality drill on special for less than $50. I bought two drills and gave one to Ron, along with his receipt. The next time I saw Ron, he explained that the drill that I bought him had failed and that he had bought a different one, with more power.

I didn't query Ron as to what kind of work he was doing, as I had now learnt that he was a "Bull in a China Shop" kind of worker who was not able to take a break when his tools become hot.

I asked Ron if he had taken his drill back for replacement, as it had a 12-month warranty. Ron said that he had thrown his receipt away along with the packaging. He offered me his non-working Ozito, in case I wanted to remove some parts from it before it went into the recycle bin.

I was curious as to what had gone wrong with Ron's brand new drill, as there was no burnt varnish smell coming from it. I carefully opened the drill casing, and could immediately see that the "Forward / Reverse" double-pole double-throw switch had deformed for some reason and the contacts were no longer touching, to make the circuit.

I was going to try to repair or replace the switch when I remembered that the unit was still under warranty. I had worked in quality control many years ago and I knew that the manufacturers liked to receive their failed products back, so that they could examine them, to find out why they had failed in actual customer service.

So I carefully reassembled the drill and took it to Bunnings, along with the receipt for my drill, and asked if it could be replaced under the Ozito warranty. I was told that the drill would have to be sent back to the manufacturer for examination, before a decision could be made.

Several weeks later I received a phone call, asking me to call in to Bunnings, to discuss my drill. I was told that Ozito would replace my drill but would also offer me a no-charge upgrade to their industrial quality drill, as they thought I would benefit from the additional power in their heavy duty machine. I was as happy as a motorist who is let off a speeding fine, to be offered a better unit for free.

Some weeks later when I went to visit Ron, I found out that we were not allowed into the backyard, due to his construction works. He had been building a deck on the back of his house and was busy drilling half-inch holes through four-inch hardwood posts. No wonder the poor little domestic duty drills had been unable to cope!

I was tempted to let Ozito know why their drill had been unable to make the grade but having gained a "You Beaut" machine for free, I thought I had better keep quiet! SC

Servicing Stories Wanted

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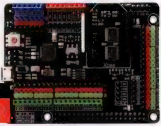

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K 6130 ~~$99.95~~ **$69**

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(SC November '14) Schedule your appliances to turn on and off with this handy kit, helps to save power and add convenience to almost any appliance. Includes a RF remote mains switch.

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NEW! K 6075 **$44.95**

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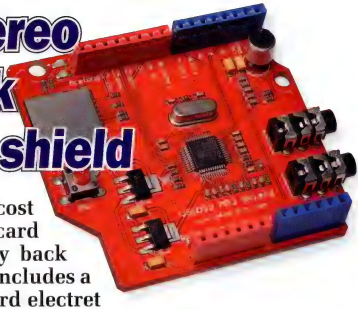
An Arduino stereo audio playback and recording shield



The VS1053 MP3 shield is a low-cost Arduino shield with a microSD card slot which can decode and play back many different audio formats. It includes a headphone output, a tiny on-board electret microphone and a microphone input, with the possibility of recording audio to the Ogg Vorbis compressed file format. It's very flexible and quite easy to get up and running.

by Nicholas Vinen

This month, we're publishing a project; found on page 77, which combines a standard Arduino board with a VS1053b-based audio playback and recording board plus an LCD and keypad, to make a programmable music and audio playing and recording device.

At its heart is the shield with the VS1053 IC, microSD card connector and a handful of other components.

Most of the audio playback and recording work, including encoding and decoding, is done by the very flexible VS1053 IC from VLSI Solutions, a Finnish "fabless" IC manufacturer.

VLSI stands for "Very Large Scale Integrated circuit" and refers to the fact that their products tend to be ICs which contain hundreds of thousands, if not millions, of transistors.

As shown in the block diagram of the VS1053 IC (Fig.1), the chip includes many large and complex blocks including: a Digital Signal Processor (DSP; a microprocessor designed to excel at signal processing tasks); read-only and random-access memory (ROM/RAM); a stereo ADC and DAC (including volume control); a stereo headphone amplifier (down to 30Ω); a microphone amplifier; a phase-locked loop (PLL; labelled "clock multiplier") and digital interface circuitry, including two serial buses.

All these functions are combined to provide a complete signal path from the microphone and line inputs to produce compressed digital data, and then take compressed digital data, decode it and drive headphones or a small pair of speakers with the resulting analog audio.

One of the keys to the power of the VS1053 is the fact that it comes pre-programmed to decode multiple different popular audio formats such as MP3, AAC, WMA and MP4.

It's based around a fully programmable signal processor and so, by uploading additional code, you can add numerous other useful functions such as the ability to encode and decode the free and open source "Ogg Vorbis" audio codec and even FLAC (Free Lossless Audio Coding).

Happily, VLSI Solutions even supply pre-written code "plugins" and provide example code to upload them to the VS1053 for these additional tasks.

The only disadvantage is the need for additional memory in your host microcontroller (ie, the device driving the VS1053) to have these plugins ready to go as needed.

In terms of performance, the VS1053 quotes a signal-to-noise ratio at full volume of 94dB and a total harmonic distortion plus noise figure of 0.07%. So it isn't quite a hifi device but then again, since it will normally be playing back digitally compressed files like MP3, you're unlikely to be able to get full CD quality out of it anyway.

It's quite a power-efficient device, using just 140mW during playback, including driving a pair of 30Ω earbuds to a reasonable volume level, and just 36mW when idle with no load.

The VS1053 comes in a 48-pin LQFP or Low-profile Quad Flat Pack. This is a surface-mount package but if you don't like soldering these, the good news is that the shield comes with all components already mounted and it barely costs any more than the IC itself.

The "Geeetech" shield

The original VS1053 Arduino shield was designed and sold by Sparkfun in the USA. If you're into Arduino you will have heard of them as they are one of the biggest sources of shields and accessories.

You may have also noticed that

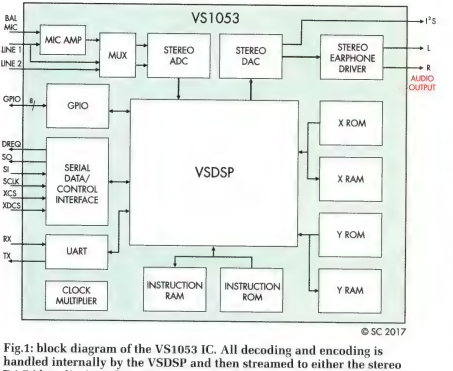


Fig.1: block diagram of the VS1053 IC. All decoding and encoding is handled internally by the VSDSP and then streamed to either the stereo DAC (decoding), or the SO register SCI_HDAT0 (encoding). The chip also contains a TTL RS-232 (UART) serial debugging interface which is not wired up by the shield.

anything they produce which becomes popular tends to lead to much cheaper, Chinese-sourced "knock-offs" which are either very similar to, or in some cases, direct copies of the originals.

While the Sparkfun VS1053 shield is better designed, it doesn't come with any microphone inputs. So the knock-off version provides the easiest way to get this features.

Sparkfun have produced shields based on newer ICs which can do more, but given the low cost of this one and its ready availability, we thought we'd have a go and see if we could build something useful around it.

If you've been paying attention to the burgeoning Chinese electronic module industry, as documented in our "El Cheapo Asian Electronic Modules" series of articles, you won't be surprised to hear that the company behind this shield, Geeetech, is based in Shenzhen, China, near Hong Kong.

Nor will you be surprised to hear that their range of products includes parts for 3D printers, Arduino type development boards and shields, UAV components (ie, drones) and all sorts of breakout and sensor boards.

Anyway, turning our attention back to this particular shield, we've traced out its circuit (which as far as we can tell, is not available anywhere else) and it is shown in Fig.2. While, as we said, it's pretty much based on the sample circuit, there are a number of odd design decisions here, some of which violate best practices and deserve an explanation.

Firstly, you will note that IC1 runs off 3.3V and 2.5V supply rails but a number of its I/O pins, including inputs, are connected directly to Arduino pins which will be driven to +5V or thereabouts when taken high. There's no mention of any 5V-tolerant inputs in the VS1053 data sheet and it gives an "absolute maximum" rating of 3.6V on all pins.

Clearly, many of these shields are in use and apparently without major problems (including our prototype).

Measurements on our prototype suggest that what actually happens when you're using the shield is that input protection clamp diodes conduct, pumping up the 3.3V supply rail to around 4.1-4.2V because of current flowing from the Arduino outputs. Apparently, the VS1053 chip is able to survive this, despite an absolute maximum supply rating of 3.6V.

This is not a design practice we would recommend. At the very least, some series resistors to limit the current would be a good idea. In fact, on the Sparkfun VS1053 shield board, a 74HC4050 CMOS hex level shifter IC is used to reduce the swing on the MOSI, CS, DCS, SCK and reset lines from the Arduino to VS1053 in order to protect the latter. So the designers of that board must have had the same misgivings that we do.

Similarly, the microSD connector is wired up to Arduino pins D9, D11, D12 and D13 directly. Each pin has a 4.7kΩ pull-up to 3.3V and thus would allow the use of open-collector outputs on the micro.

But the ATmega8 chip used in most Arduino boards doesn't have direct support for open collector outputs and the 4.7kΩ resistors would severely limit the signalling speed on these lines anyway.

So again, it seems that the designers are relying on the microSD card to be 5V tolerant, or its internal clamp diodes to avoid damage. It seems to work, but we wouldn't have designed it this way.

As mentioned above, the MOSI and SCK lines which are shared between the SD card and VS1053 IC are level-shifted by the 74HC4050 IC in the Sparkfun shield. The remaining spare channel on that IC is also used to reduce the swing on the CS line for the microSD card down to 3.3V.

One possible solution to the lack of level-shifting would be to use an Arduino host board which runs off 3.3V, although these are not very common.

Turning back to the shield, the next odd thing you will notice if you peruse the VS1053 data sheet is that it specifies another "absolute maximum" rating, this time for the processor core supply voltage (CV_{DD}) of 1.85V. And yet the Geeetech shield uses a 2.5V linear regulator to provide this rail!

We don't know if it's because Geeetech found a skip bin full of 2.5V regulators, or if they found that the chip performed better with a 40% higher core supply voltage than recommended.

It's even possible (though unlikely) that the VS1053 chip on the shield is itself a knock-off which needs a higher supply voltage. Regardless, the shield works fine but it certainly is a bit weird.

One nice feature of this shield is that it incorporates an on-board electret

microphone (with interface circuitry exactly as suggested in the VS1053 data sheet) along with a 3.5mm line-in jack socket, fed to two separate inputs on the main IC.

Note though that only the tip connector of the jack socket (labelled "MIC") is wired up, so you can only record in mono.

At the playback end, the outputs are fed directly to another 3.5mm jack socket, this time in stereo. But the sleeve of this connector is not wired to ground, rather, it goes to the "GBUF" output of IC1 which provides a buffered reference voltage, at the same level as the quiescent voltages for the LEFT and RIGHT output pins.

This is fine for driving headphones or earphones directly, or even small passive speakers (although they will have to share the negative connection).

However, you may run into trouble if you are connecting the output to an amplifier, if that amplifier's ground is Earthed and so is your Arduino board (through any connection between a ground and Earth). This will effectively short the GBUF voltage out.

In that case, you will need to connect DC-blocking capacitors in series with the left and right signals. Such capacitors are a feature of the Sparkfun shield, but not this one.

The good news though is that provided the input impedance of your amplifier is high, they don't need to have an especially high value. 1µF plastic film (MKT/MKP) capacitors should do just fine.

The VS1053 derives timing, both for its CPU and sampling clocks, from a 12.288MHz crystal. This is stepped up internally by a PLL to provide the CPU clock of around 54MHz.

There are two LEDs on the shield. One is red and is connected across the output of the 3.3V regulator, indicating the presence of power, while one is green and is connected between the CS line and ground, indicating activity. Both have a 1kΩ series current-limiting resistor.

The DREQ output of IC1 is connected to Arduino pin D2. This is used to signal the Arduino to feed more audio data or to indicate when the VS1053 is ready for commands. The Arduino is normally configured to generate an interrupt when this goes high.

You may have noticed that the VS1053 IC has several GPI/O pins which can be set up by the user for various purposes.

Most of them are not connected to anything on this shield, or simply have 100kΩ pull-down resistors connected. GPIO0 doubles as the "SPIBOOT" line and needs a 100kΩ pull-down so that it will boot off its internal memory rather than trying to load its boot data over an SPI bus.

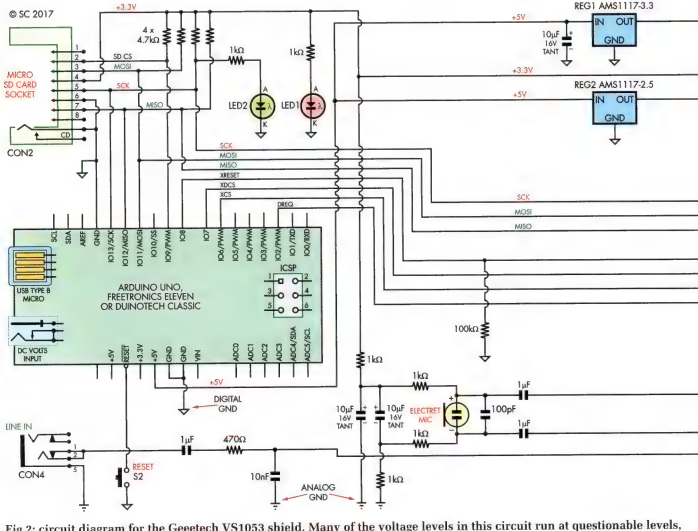


Fig.2: circuit diagram for the Geeetech VS1053 shield. Many of the voltage levels in this circuit run at questionable levels, such as the +2.5V line delivered to CV_{DD} (40% higher than the maximum 1.85V).

siliconchip.com.au

Similarly, GPIO1 needs a pull-down as it will activate "real-time MIDI mode" if held high when the chip emerges from reset. We're not sure why GPIO4 has a pull-down resistor as it doesn't seem necessary.

Finally, the shield provides a reset button which parallels the Arduino's, in case the one on the main board is inaccessible with the shield plugged in.

Driving it from an Arduino

The Arduino can read or write data on the microSD card using the MISO/MOSI/SCK 3-wire SPI bus on pins D11-D13 while it's driving the SD_CS line on pin 9 low.

The X_CS and X_DCS lines on pins D6 and D7 are left high during this time, so only the microSD card is being addressed.

The VS1053 itself has two SPI serial buses, one for control (SCI) and one for audio data (SDI); the SCI control interface is selected by bringing pin D6 low, while the SDI data interface is selected by bringing pin D7 low. The VS1053 also has a TTL RS-232 (UART) serial debugging interface, however, that is not connected to anything on this shield.

The X_RESET line on pin D8 has a 100kΩ pull-down resistor and this holds the VS1053 in reset until the Arduino is ready to control it.

D8 must be brought high before sending any commands or data to the VS1053 chip. The only additional line required to control the VS1053 from an Arduino is the DREQ line on pin D2, mentioned earlier.

We're using the freely available SFEMP3 library to drive the VS1053 from an Arduino Uno-compatible module, along with the venerable SdFat library to read audio files off the microSD card. The SFEMP3 library code (which also comes with SDFat) can be downloaded from:

www.billporter.info/2012/01/28/sparkfun-mp3-shield-arduino-library/

Note that while the SD card and VS1053 IC share the same SPI bus, unfortunately, it hasn't been arranged so that data can be streamed directly from the SD card to the VS1053.

That's because data from the SD card appears on the MISO (master-in, slave-out) line as the SD card is the slave in this case, but data fed to the VS1053 must go on the MOSI (master-out, slave-in) line for the same reason.

This means that the Arduino must actively read data off the SD card and then write it back over the same bus to the VS1053. That doubles the effective bandwidth required.

Still, while playing back a 128kbit audio file (fairly typical), that only occupies about 10% of the Arduino's time, leaving plenty of time for other tasks.

Unfortunately, while the VS1053 and the Geeetech shield both support recording, the SFEMP3 library does not. However, all the code and information required to enable recording are available from the VLSI website at: **www.vlsi.fi/en/support/software/vs10xxplugins.html**

Thankfully, while their website is a bit difficult to navigate, their documentation is comprehensive.

If you want to get started with this shield, we suggest you read the project article in this issue which takes you through building a fully functional audio player based on this shield.

Your other option is to download the SFEMP3 library and its example sketch and load that into your Arduino module.

Some of the functions available in the SFEMP3 library include:

- setVolume(vol) – sets the playback volume, either for both channels, or for each individually; a value of 40 is used for 100%
- setBassFrequency(Hz)/setBassAmplitude(dB) – allows you to apply bass boost or cut
- setTrebleFrequency(Hz)/setTrebleAmplitude(dB) – allows you to apply treble boost or cut
- playMP3(filename, time) – play the MP3 (or other file) with the given name starting from the given time

- stopTrack() – stops playback
- isPlaying() – returns true if a file is currently being played or is paused
- skip() – go forwards or back by up to 32.5s each time
- skipto() – jump to a point in the file, limited to the first 65.5s
- currentPosition() – returns a value indicating how many milliseconds of audio have been played from the current file
- pauseMusic()/resumeMusic() – self-explanatory
- setVUMeter(on) – enables or disables VU metering
- getVULevel() – indicates the current VU level, in dB, for both channels

Plugins enable other features

In addition to the plugin enabling Vorbis encoding, there are a number of others available, which fix bugs and add extra capabilities. One plugin which is highly recommended is the "VS1053b patch w/FLAC decoder", available from:

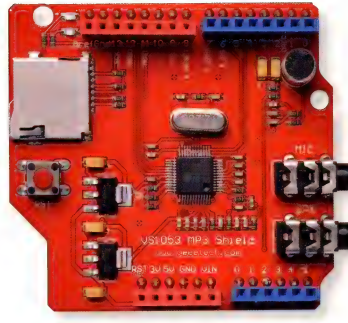
www.vlsi.fi/en/support/software/vs10xxpatches.html

This fixes a number of bugs, along with adding the ability to decode losslessly compressed FLAC files.

Other plugins can add functionality which include:

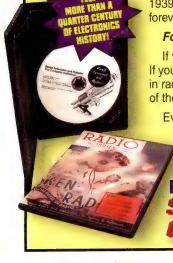
- a multi-band equaliser
- a sine/DTMF waveform generator
- a PCM audio mixer which allows the microcontroller to feed audio to the chip which is digitally mixed with audio from the file being decoded
- a mic/line input mixer which allows input monitoring during playback, including mono down-mix capability
- a pitch shifter plugin which allows changing the pitch of the audio without changing temporarily
- a plugin which makes rewinding/fast-forwarding WMA files easier
- a package of "loudness" enhancing filters

These are in addition to built-in features of the VS1053b which we haven't mentioned yet, including zero-crossing detection for smooth volume changes, quiet power-on and power-off and a 64-voice MIDI synthesiser. SC



A top view look at the shield (larger than life size) gives us a better overview of all the components used in it. You can see the on-board electret microphone, the microphone input and speaker output populate the right-hand side of the board (from top to bottom).

Radio, Television & Hobbies: the COMPLETE archive on DVD



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Music Player

by Bao Smith

Got some music stored on your SD Card? Here's an Arduino-based player that handles most common formats. It's cheap, easy-to-build and it will even record as well. Build it . . . and be amazed!

This project uses an Arduino "MP3 shield" described in greater detail on page 72 of this issue. This delivers audio to a 3.5mm stereo jack which can be plugged directly into earphones/headphones or to an audio amplifier to power larger speakers. For recording, it has an on-board electret microphone along with a mono 3.5mm jack socket, which allows an external microphone to be used.

All the audio decoding/encoding and playback/recording functions are handled by the VS1053 IC on this shield. For more information on that IC, see the separate article on the shield.

As well as playing back the compressed formats listed in the introduction, this IC is also capable of playing back General MIDI files and also uncompressed WAV files. It's an impressive chip, with quite a few extra features that we aren't using in this project, such as digital tone controls. And of course, you can modify the software to take advantage of those features if you want to.

While this device is capable of playing back a number of formats, most constructors would use it to play back either MP3 or AAC files, which are the de-facto standard formats for digitally compressed audio.

Pretty much any music player should play back these formats. Until recently, MP3 was patented and so required licensed software for decoding. But that patent (held by the German firm Fraunhofer IIS) expired on the 23rd of April this year, so it is now an open format.

Because it was patented, the similar open-source Ogg Vorbis standard was established. And more recently, AAC was developed, aimed mainly at providing either higher audio quality than MP3 at the same file size, or (in the case of AAC+) reasonable quality with a much smaller file size (bit rate).

We've chosen to use the VS1053-based Arduino shield because it is low cost, can play back all these file types and has a decent on-board DAC which is able to power nominally 30Ω loads such as many headphones and earphones; the minimum nominal load impedance it can handle is 16Ω.

Construction

Building this project is quite simple, with most of the connections made either by plugging a shield directly into the Arduino board or by connecting an external module to that same board using one of 12 short jumper wires. These are fitted with a male DuPont connector at one end and a female at the other.

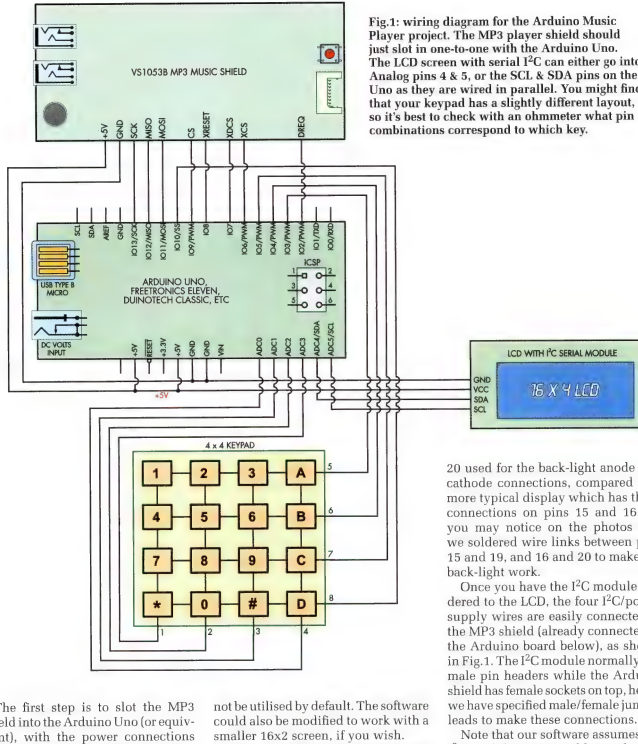

Fig.1: wiring diagram for the Arduino Music Player project. The MP3 player shield should just slot in one-to-one with the Arduino Uno. The LCD screen with serial I²C can either go into Analog pins 4 & 5, or the SCL & SDA pins on the Uno as they are wired in parallel. You might find that your keypad has a slightly different layout, so it's best to check with an ohmmeter what pin combinations correspond to which key.

The first step is to slot the MP3 shield into the Arduino Uno (or equivalent), with the power connections matching up and the SD card slot on top of the USB connector. While you can upload the software at this point and start experimenting, with control via the USB serial monitor in the Arduino IDE, we will describe the remaining assembly steps first.

The next job is to get the serial LCD screen running. We used a 16x4 screen but it will also work with a 20x4 alphanumeric display, however, you will need to modify one line in the software and the whole screen will not be utilised by default. The software could also be modified to work with a smaller 16x2 screen, if you wish.

Refer to Jim Rowe's El Cheapo Modules series article titled "part 5: LCD modules with I²C" in the March 2017 issue for details on how these I²C LCD modules work.

If you haven't already fitted the I²C module to the LCD, generally it's just soldered on the back, with a 1:1 correspondence between its pins and those on the main LCD board.

We used a slightly unusual LCD module that we have on hand with a 20-pin connector, with pins 19 & 20 used for the back-light anode and cathode connections, compared to a more typical display which has these connections on pins 15 and 16. So you may notice on the photos that we soldered wire links between pins 15 and 19, and 16 and 20 to make the back-light work.

Once you have the I²C module soldered to the LCD, the four I²C/power supply wires are easily connected to the MP3 shield (already connected to the Arduino board below), as shown in Fig.1. The I²C module normally has male pin headers while the Arduino shield has female sockets on top, hence we have specified male/female jumper leads to make these connections.

Note that our software assumes the I²C module uses an address of 0x3F; some I²C modules use a different address (eg, if it uses a PCF8574T [0x27] rather than the PCF8574AT). So we suggest you check the supplied documentation and if necessary, change the LCD address in the software before uploading it.

The final set of connections to be made are between the 4x4 keypad and MP3 shield as shown in Fig.1. We're using a standard switch matrix type of keypad which is commonly available.

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If your keypad doesn't have any pin headers but rather has a series of pads with holes on its PCB, you will need to solder a male pin header onto it before proceeding (straight or right angle).

The 4x4 keypad uses eight connections, four for the rows and four for the columns. After deducting the pins used by the "MP3 shield" and LCD, we're left with ten free pins on the Arduino module and only a few of these are digital pins. Luckily, analog pins can also be configured as digital I/Os, so wire up the keypad as shown in Fig.1.

Note that your keypad may use different row and column connections to ours but you can easily check this by setting a DMM in continuity mode, connecting it across each pair of pins and pressing each key on the keypad. You should quickly be able to determine which pins connect to the rows and columns.

Note that after plugging in the keypad, the only pins remaining to connect anything else to your board are digital pins D0 and D1. If you do need to add other devices, consider using I²C devices which can be simply wired up in parallel with the LCD as long as they do not use the same I²C address.

Software operation

We won't go into much detail regarding how the software works here; you can download and examine the code if you want to see how it works, or make any changes.

However, it can be helpful to know how audio data is piped to the VS1053. The VS1053 has a 2048-byte buffer which can receive up to 32 bytes of data at a time. The data is sent via an SPI serial bus when the DREQ pin is high (this pin also indicates the chip is ready to receive a command over the SCI interface).

Data can be sent either most-significant byte first (SM_SDIORD [0x9] set to 0) or least-significant byte first (SM_SDIORD set to 1) format; the SM_MODE register address is 0x4800 and this is configured over the SCI interface.

The software requires four libraries to function, with one of them requiring minor changes to the code. The libraries required are SdFat, SFEMP3Shield (**https://github.com/madsci1016/Sparkfun-MP3-Player-Shield-Arduino-Library**), LiquidCrystalI2C (**https://github.com/fdebrabander/Arduino-LiquidCrystal-I2C-library**) and Keypad (**http://playground.arduino.cc/Code/Keypad#Download**).

It's important to mention that the version of SdFat we are using will only open files that use the old DOS 8.3 file naming convention (8 characters for name, 3 for extension). Files with names that do not match this format will not display properly and may cause other problems. The reason for this restriction is to save on memory.

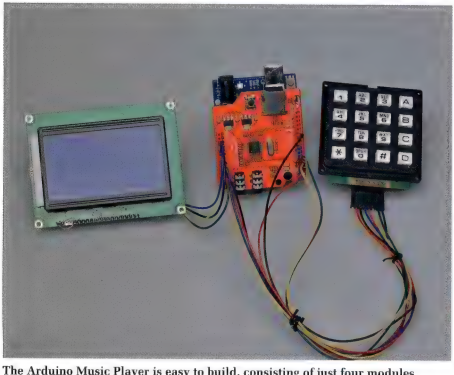
The software could be modified to support long file names but given that the basic Arduino module only has 32KB of flash and 2KB of RAM, and our software pretty much fills this, you would need a more powerful Arduino board to use the modified software (eg, one with an ATmega2560 chip rather than ATmega328).

The software is capable of uploading various patches or "plugins" to the VS1053b chip. These can fix bugs in its firmware or add extra capabilities. They are stored in "little-endian" binary format on the microSD card, with a file extension of ".053".

These files can be created from .plg plugin files downloaded from VLSI's website (**www.vlsi.fi/en/support/software/vs10xxpatches.html**), using a conversion tool that comes with the SFEMP3Player library called "vs_plg_to_bin.pl".

Note that you might have trouble running the above Perl script if your version of Perl is lower than 5.10.0. As on line 59, a parameter for the pack() function makes use of the "<" modifier to force the data to be stored in little-endian format. You remove this modifier if you know your CPU architecture will only deal with data in little-endian format, or alternatively, you can set SM_SDIORD to 0 when sending the plugin data.

The reason for converting them is to save storage space and speed up loading them into the VS1053b IC; even when converted to binary form, they can be quite large. The SFEMP3 library supplies some plugin files along with the software, already having been converted to this format. Their uses are described below.



The Arduino Music Player is easy to build, consisting of just four modules which plug together; either directly or via jumper leads.

Installing the software

If you don't already have the Arduino integrated development environment (IDE) on your PC, download it and install it now. It's available for free, from **www.arduino.cc/en/Main/Software** We used version 1.6.12; SdFat requires version 1.6 or higher of the Arduino IDE to function, but it would be possible to convert it to function on earlier versions.

Make sure all four libraries mentioned above have been installed or

you will not be able to compile the software. Minor changes were made to the SFEMP3Shield software to expose some internal functions required by our sketch.

This modified version of the library will be included in the download package on the SILICON CHIP website, along with the actual sketch itself. Once you have the library ZIP files, you can install them in the Arduino IDE via the Sketch→Include Library→Add .ZIP Library menu option.

You will also need the two VS1053b plugin/patch files named "patches.053" and "oggenc.053", also included in that download package. When the sketch runs, it looks for these files in the root directory of the microSD card, loads them into its memory and then uploads them to the VS1053b IC.

The first patch file is an update to the chip's firmware that fixes some bugs and also adds extra capabilities. Some of the bug fixes are required to play certain audio files that would otherwise return errors.

The second is the code which allows the chip to record in Ogg Vorbis format. Without these files, the unit will not function properly. Once you've placed these files on the microSD card, along with whatever audio files you want to play back, plug it into the socket on the shield.

Note that the SD card should be formatted with either FAT16 or FAT32 file systems to work with the SdFat library.

Having ensured the libraries are installed, open up the sketch (called "VS1053_example.ino") in the Arduino IDE and plug the Arduino into your PC using an appropriate USB cable.

We assume you know how to select the appropriate USB serial port in the Arduino IDE; if you're unsure, we've described this procedure before, for example, in the Arduino-based Digital LC Meter article, published in the June 2017 issue (on pages 35 and 36).

You can now use the Sketch→Upload menu item to load the software into the Arduino.

Using the module

When the software has been loaded and the module is up and running, you should notice that the display has lit up and menu should be shown. This menu can be navigated using the keypad with the keys labelled 2/8 corresponding to up/down, 4/6 to left/right, 5 being "enter" (selecting the menu entry that the cursor is currently on) and * functions as a general "back" key in all menus.

The menu items that are available on the main menu, by default, are:

0. plays all music files available on the SD card. Pressing 4/6 will go to the previous/next song, "A" will restart the song from the beginning, 5 will pause/unpause, 1/3 will decrease/increase playback speed and 7/9 will increase/decrease playback volume.
   During playback, it will display the file name, current time and a VU meter signal level for the left and right channel. Playback can be stopped by pressing the "*" key and it will stop automatically after the last file has been played.
   Note that there is a limit of 50 files due to memory constraints (2 bytes are required per file). The software could be modified to remove this limitation but then it would not be possible to step backwards, to the previous file; you could only skip forwards through the list.
1. lets you select a file to play.
2. record to an .ogg file named recordXX.ogg, where XX starts at 00 and is incremented per recording.
3. toggles between mono and stereo output
4. resets the VS1053 chip to its default settings
5. produces a test sinewave from the outputs
6. turns on/off the differential output mode
7. put the VS1053 IC in low-power sleep mode
8. exit sleep mode

Recording uses the on-board electret microphone. If you want to use the line input instead, you need to add a line at the top of the sketch which reads "#define USE_LINEIN" without quotation marks. The audio is recorded in Ogg Vorbis format at approximately 128kb/s and saved as an ".ogg" file.

In addition to the keypad/LCD interface described above, the software can be controlled from your PC using the serial monitor.

You simply read the menu options that are displayed on the serial monitor and choose one by pressing the associated key on your keyboard. This interface has additional options which can be used for debugging.

Making simple changes to the code

Experienced programmers should have no problems changing the software to suit their needs but even relative beginners can make some changes, as described below.

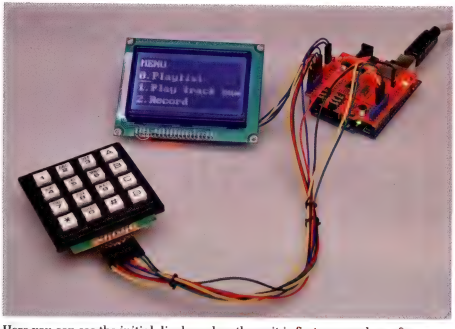
A constant called MAX_INDEX defines how many files the software can handle on the microSD card. Changing this will also affect how much SRAM is used. If you increase it too much, there won't be enough free memory for the software stack and it will no longer work properly. Each additional entry will take another 2 bytes of SRAM.

The definitions LINE1, LINE2, LINE3 and LINE4 are the addresses of each line of the display on your LCD module. The module we used has the first line at address 0 hex, the second line at 40 hex, the third line at 14 hex and the fourth line at 54 hex.

This is pretty standard and most displays should use the same addresses, but if yours is only displaying the first line correctly, you may need to change these.

Parts List

1 Arduino Uno or equivalent with ATmega328 chip (Jaycar Cat XC4410)
1 Geeetech Arduino MP3 Player Shield (SILICON CHIP online shop Cat SC4315)
1 20x4 or 16x4 LCD screen with I²C backpack module (SILICON CHIP online shop Cat SC4203)
1 4x4 matrix keypad (other sizes will also work with software changes)
1 8-pin header, 2.54mm pitch, straight or right angle (to suit keypad)
12 male-female DuPont jumper leads (Jaycar Cat WC6028)
1 USB Type-A to Type-B "printer" cable (to suit Arduino module)
1 microSD card formatted in FAT16/32, capacity to suit application
1 7-12V DC plugpack with 2.1mm inner diameter plug (optional, for standalone use)



Here you can see the initial display when the unit is first powered up after loading the software, showing part of the main menu. The underline indicates which menu item will be selected when you press enter (5 on the keypad).

Our I²C LCD uses the PCF8574AT IC and so the software is set up from an I²C address of 3F hex. If your LCD interface has a PCF8574T, change the line which reads:

```
LiquidCrystal_I2C lcd(0x3F,
  LCD_COLS, LCD_ROWS);
```

to:

```
LiquidCrystal_I2C lcd(0x27,
  LCD_COLS, LCD_ROWS);
```

Regarding the changes made in the SFEMP3 library for this project, they can be summarised as the following:

1) playTrack(uint8_t) was changed to playTrack(uint16_t) to allow more than 255 files on the same card (using the naming scheme trackX.mp3, where X is a number between 0-999).

2) isFnMusic(char *) was changed to also check for Ogg Vorbis files.

3) the following functions in the SFEMP3 class were changed from "private" to "public" to allow the sketch more control over the VS1053b IC:

```
void getTrackInfo(uint8_t, char*,
  uint8_t); // Gets MP3 ID3
  metadata (force appends a
  null-byte)
static void
  Mp3WriteRegister(uint8_t,
  uint16_t); // Write 16-bits to a
  given register
static uint16_t Mp3ReadRegister
  (uint8_t); // read from a given
  register
uint8_t VSLoadUserCode(char*);
  // Load a .53 format plugin
```

Additional uses

As noted earlier, the SFEMP3Player library has treble and bass controls, however, our software does not use these functions.

If readers want to work on the software, this would be one area to start. Another improvement that could be made is to take advantage of the library's functions for reading header information (eg, ID3 tags), and display it on the LCD during playback.

The chip itself is surprisingly powerful, handling all the decoding/encoding itself in real time. It can also be used as a graphic equaliser and MIDI synthesiser.

VLSI also offer software to use the chip as a FIR (finite infinite response) filter, in combination with the free GNU Octave software. This can be found under VSIDE DSP Library:

www.vlsi.fi/en/support/software/vs10xxapplications.html

Using it is outside the scope of this article, though.

The VS1503 manufacturer's website can be found at www.vlsi.fi/en There you can find other example programs (not for Arduino) along with a list of patch files (www.vlsi.fi/en/support/software/vs10xxpatches.html) and bonus functionality that can be loaded into the chip. SC

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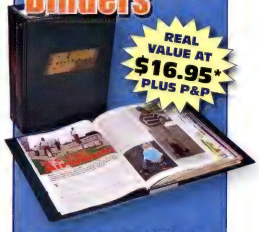

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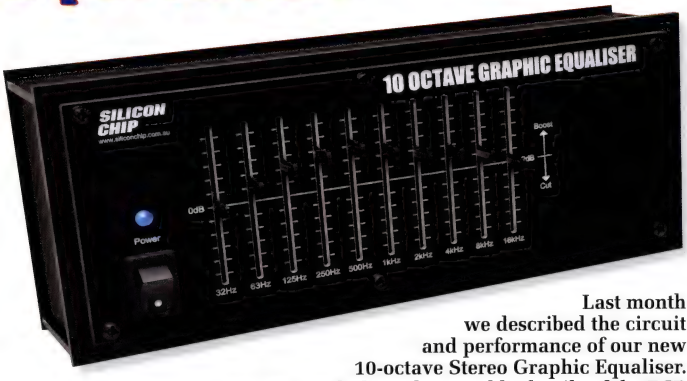


Last month we described the circuit and performance of our new 10-octave Stereo Graphic Equaliser. Now we conclude with assembly details of the PCB and the acrylic case with its very smart-looking front panel, which is actually a black screen-printed PCB – with slots for the sliders but no tracks!

By JOHN CLARKE

For such a large circuit, the double-sided PCB for this project is surprisingly compact at only 198 x 76mm. It is coded 01105171.

It is very compact because we have mounted the 10 ganged slider pots on one side and all the active circuitry, with 12 (or 13) LM833 low-noise dual op amps, on the other side.

Virtually all of the resistors are surface-mount types but fortunately you can read their printed values (with a magnifying glass).

All of the capacitors, apart from 12 (or 13) 100nF surface-mount ceramic bypass caps, are through-hole types, so while some components are quite small, they are also quite straightforward to solder in place.

And the benefit of soldering the surface-mount components is that you don't have to clip off their pigtails after soldering.

The PCB front panel shown in the prototype above is a little smaller than the acrylic case but we have since modified it so that the outside dimensions of the front panel and case are the same – it looks neater.

Mind you, the acrylic case is not needed if the equaliser is to be mounted into existing equipment or into a half rack width 2U case – but you will still need some form of front panel.

Choice of supplies

We have provided two component overlays for the PCB, one for the AC-powered version and the other for the DC-powered version. The main difference is that the DC version omits the components for the low voltage AC power supply but adds the circuit components associated with IC13, as depicted on page 24 of last month's issue (June 2017).

To assemble the PCB, you will need a fine-tipped soldering iron bit,

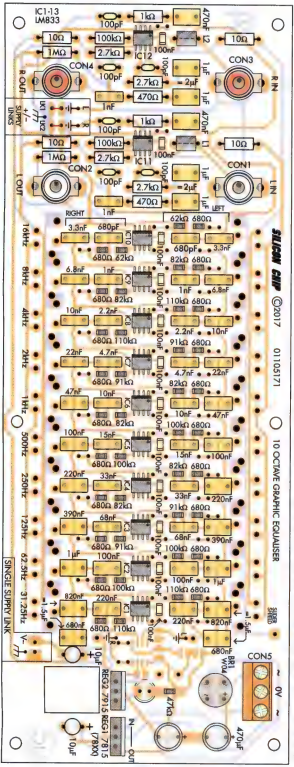
0.71mm-diameter solder, a good light and a magnifying glass or spectacles to be able to solder the surface-mount components in place.

Begin by mounting the surface-mount ICs. As already noted, IC13 is only installed if you intend to use a DC supply.

Each IC is firstly oriented correctly and note that the chamfered side is the pin 1-4 side of the IC. Place the IC in position over the PCB pads and solder one corner pin. Check its alignment and remelt the solder if the IC needs adjustment. When the IC is aligned correctly, solder the remaining seven pins. Make sure that there no solder dags bridging any of the adjacent pins.

Then align and solder the 100nF supply bypass capacitors for IC1-IC12 (and for IC13 if used). Then the surface-mount resistors can be soldered in place including that for LED1 and those resistors used for the DC version, if that is the version being built.

We said that the surface-mount resistors have the values printed on them but some "interpretation" is required. A 3 or 4-digit code is used, with the last digit being the number of zeros.



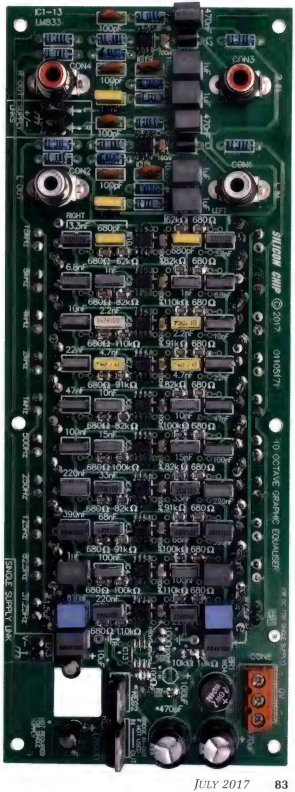


Fig.7 (left): use this component overlay (and the matching photo at right) if you want to use an AC supply. It contains the bridge rectifier, smoothing capacitors and most importantly the positive and negative 15V regulators. Note also the supply links (top left) – both are in place. In the photo these are shown as header sets but as these would normally be set once and forgotten, wire links (from component lead offcuts) would be the way to go.

So the 680Ω resistors will be labelled 6800, ie, 680 with no extra zeros. The 100kΩ resistors will be 100, with three zeroes, ie, it is labelled as 1003.

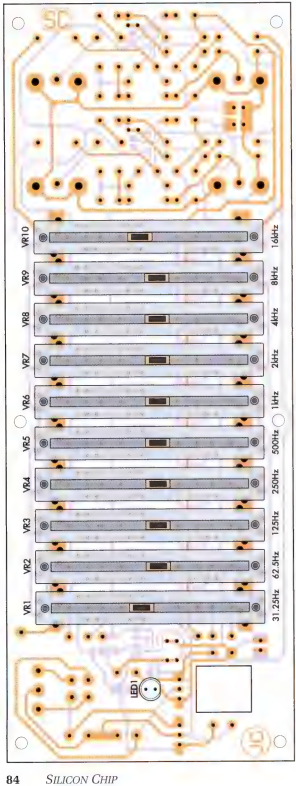
Once all the surface-mount components have been installed, the through-hole components can be mounted. Start with the resistors and then fit the two ferrite beads, using a resistor lead offcut to feed through each bead before soldering them in place.

Then install the MKT polyester capacitors. Note that the 820nF and 680nF capacitors for the 32Hz gyrator are connected in parallel to make up a value of 1.5µF. Alternatively, you could use 1µF and 470nF capacitors instead, if the 680nF and 820nF values prove difficult to obtain.

The electrolytic capacitors are mounted next, taking care to orient each one with the correct polarity.

When mounting the RCA sockets, the white ones are for the left channels and the red are for the right channels. The 3-way screw terminal CON5 is mounted with the opening to the edge of the PCB.

Take care when mounting the bridge rectifier, making sure that its pin labelling matches the screen printing on the PCB. REG1 (and REG2 if used) can be installed next, seated as far down onto



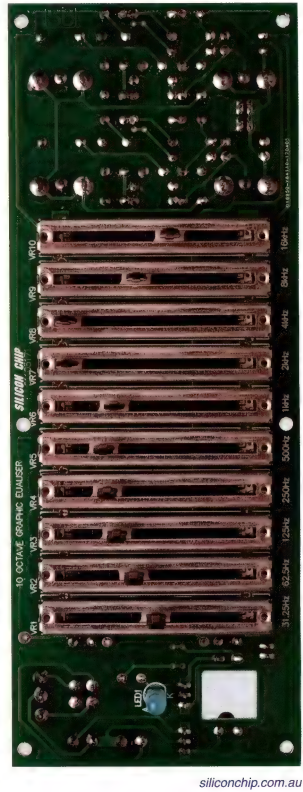


Fig.8: the top side of the PCB contains only the 10 slider pots and the power LED; everything else is on the underside. Again, the matching (same size) photo at right will assist you in PCB assembly. The square hold in the board is to accommodate the power switch, itself attached to the front panel.

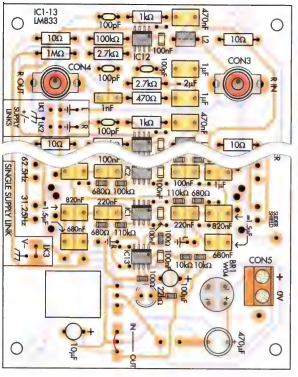


Fig.9: use this alternative PCB overlay if you are using a DC supply. Only the two end sections of the PCB are shown – the centre of the PCB is identical. Note the absence of links for LK1 and LK2 but the link over three pads at the bottom (this would be easiest achieved on the underside of the board).

the PCB as they will go.

For the DC supply version, you can use a 15V regulator (7815) if the DC source is between 18V and 25V (maximum). If the supply is less than 18V, a 12V regulator (7812) can be used provided the DC input is 15V or more.

Below this 15V, you can dispense with the regulator and connect a wire link between the IN and OUT terminals; the two outer pads for the component).

Naturally, this will mean the supply is unregulated.

Headers LK1 & LK2 or LK3 can be installed next. LK1 & LK2 are for the AC version and LK3 for the DC version. Install the jumper links on LK1 & LK2 for the AC powered version and a jumper link on LK3 for the DC version.

That should complete all the components installation, apart from the 10 sliders and LED1, which are mounted on the other side.

So it is most important that you carefully check that you have installed and soldered all the parts correctly before moving the to the next stage (with the sliders).

In particular, double check parts placement for the capacitors that mount directly opposite the sliders. Once the sliders are installed, you will not have access to the soldered connections for any of these capacitors.

Before mounting the sliders on the front of the PCB, make sure that all of the capacitor leads that were soldered on this side of the PCB have been trimmed back.

This must be done so that the sliders can be fully seated onto the PCB.

Note that the sliders only fit with one orientation. So if they don't seem to fit, try the alternative 180° orientation.

LED1 also needs to mount with the correct orientation (longer lead is the anode) and with the top of the lens 12mm above the PCB.

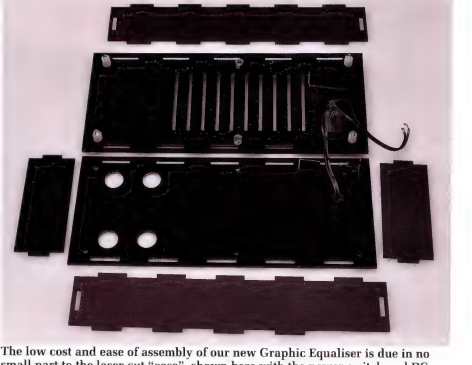
Initial testing

Power can now be applied to the equaliser circuit to test for voltage at the op amps. For the single 16VAC supply, connect the supply leads between an AC input (one of the outer terminals of CON5) and the centre 0V terminal.

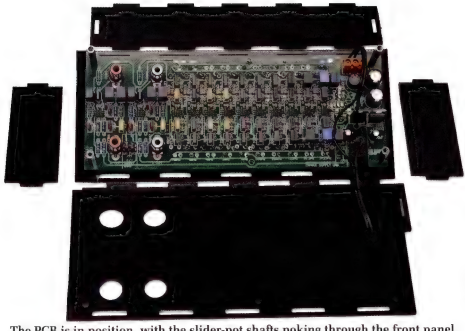
If your supply is from an existing piece of equipment with a 30V centre tapped transformer, connect the two AC voltages to each of the outer terminals of CON5 and the centre tap to the centre 0V terminal. The transformer must be capable of supplying the extra current drawn by the equaliser circuit (55mA typical, so allow for, say, 100mA).

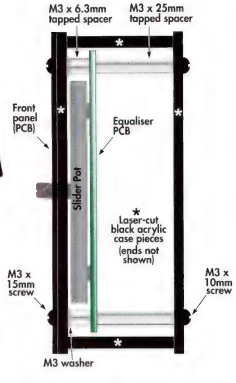
Power up the circuit and the LED should light. Now measure the DC voltage between pin 4 and pin 8 of one of the op amps. This should be close to 30V if you are using the AC supply and 15V (or less depending on whether you have a 12V regulator or if it is bridged out).

For the DC supply version, check that voltage between pin 4 of any IC to pins 3 and pins 5 shows half the supply voltage. In other words, this voltage should be +7.5V or thereabouts if you have a 15V supply between pin 4 and pin 8.



The low cost and ease of assembly of our new Graphic Equaliser is due in no small part to the laser-cut "case", shown here with the power switch and DC supply socket fitted.





The PCB is in position, with the slider-pot shafts poking through the front panel and the board held in place with threaded spacers. The diagram at right (Fig.10) shows how the PCB and case components fit together

Case installation

Fig.10 shows the assembly of the Acrylic case.

Note that we show the mains transformer in the circuit for the centre-tapped 30V supply but a transformer will not fit in the acrylic case.

In addition, the power switch used in the case is not intended for switching mains voltages which could otherwise induce hum into the graphic equaliser circuitry. The power switch is only intended for low voltage switching.

For the DC supply, the polarity needs to be correct and this depends on the wiring to the plug that connects to the socket. There will be no power supplied to the circuit if polarity is incorrect.

You need to have the positive connected to the outer terminal of CON5, so swap the two leads to the DC socket if the voltage is reversed. The wiring to the switch and socket are covered in heatshrink tubing.

The case is assembled as shown with the front panel PCB attached to the front of the case using M3 x 15mm screws secured with tapped M3 spacers 6.3mm long. These are placed at the four corner mounting positions on the PCB.

A washer is placed under each spacer first to increase clearance.

The two mounting holes in the middle of the PCB, top and bottom are secured to the front of the case with M3 x 10mm screws and M3 nuts.

The main equaliser PCB then is placed over the screws protruding through the 6.3mm long spacers and with the slider adjustment shafts protruding through slots in the front panel and front PCB.

The PCB is secured using the M3 x 25mm spacers. The rear panel of the case is secured to these spacers using M3 x 10mm screws after the top and side pieces of the case are attached in place.

The holes in the rear of the case for the RCA sockets are made with large enough clearance, so that RCA plugs can pass through hole and onto the sockets.

So connect up your new equaliser for a new listening experience.

Enjoy! SC

And finally, the case components are slotted together ready for the PCB/front panel assembly to be slipped into place and screws fitted to the four threaded spacers to complete assembly.

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Remote water level monitoring using LoRa and Arduino

In the Circuit Notebook pages of the January 2017 issue, my circuit on a LoRa remote repeater was published. The transmitter unit used included an HC-SR04 ultrasonic distance sensor which was notionally for measuring water levels, however, it wasn't fully utilised in that project.

Since then, the design has been extended to monitor the water levels in a number of different discharge ponds, in order to ensure that none of them overflows and results in pollution of the surrounding area.

Therefore this project is suitable for monitoring the water level of a swimming pool, rainwater tank or other body of water, as long as you can mount the unit in such a way that the distance from the ultrasonic rangefinder to the surface of the water varies as the water level changes.

Like the previously mentioned project, this one also uses a LoRa long-range 433MHz digital radio module, giving it an operating range of several kilometres, as long as you have line-of-sight between the transmitter and receiver, and use modules with decent antennas. I used an E32-TTL-500 module which comes with a suitable whip antenna.

The circuit is based around an ATmega328P processor (IC1) programmed using the Arduino IDE but by default it's just a bare chip without a crystal oscillator. So the chip is programmed with a bootloader that allows it to run off its internal oscillator.

This micro constantly measures the water level using the ultrasonic rangefinder connected to pins 16 and 17. It also has a Neo-7M based GPS module, which sends data over a serial interface between pins PB0 and PB1 (14 and 15) of the micro.

Both the distance (ie, water level) and position are then transmitted via the digital radio, connected to the PD2-PD6 pins of the micro (pins 4, 5, 6, 11 & 12 respectively).

The GPS latitude and longitude information is included, so that when multiple water level monitor transmitters are used, it's easy to determine where the data is coming from. Their location and water level could even be plotted on a map.

The circuit is powered from a 6V, 5.5Ah sealed lead-acid battery via an LM2940CT-5.0 regulator, which

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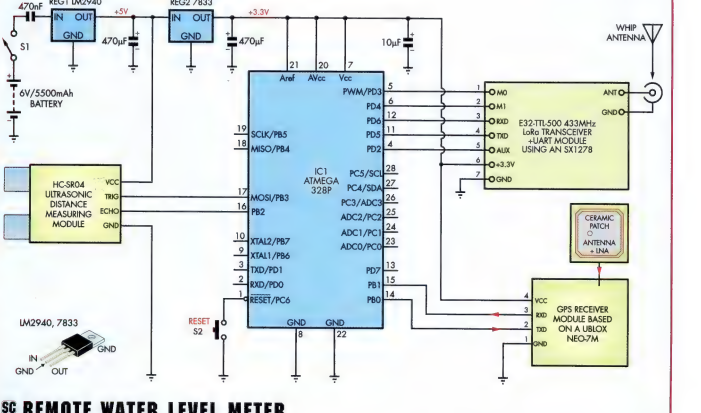


REMOTE WATER LEVEL METER

provides 5V to the HC-SR04 module and then on to a 7833 regulator which derives the 3.3V supply for IC1, the GPS receiver and the LoRa transmitter. Not shown on the circuit is the 10W solar panel which keeps the battery charged.

A receiver circuit is not shown since all you need is another E32-TTL-500 module wired up to a USB/serial adaptor, with that adaptor supplying the 3.3V to run the radio transceiver module and with the TXD/RXD pins wired up to the USB/serial adaptor's RXD and TXD pins respectively.

You can then open the USB serial port in a terminal emulator to begin receiving the data packets sent periodically from the transmitter unit(s). All the transmitters use the same (default) channel/frequency.

A sample of the received data looks like this:

32.088690, 74.648170, 12:22:20, 8.0, Loc-2
32.088690, 74.648178, 12:22:41, 8.0, Loc-2
32.088720, 74.648178, 12:23:02, 194.0, Loc-1
32.088751, 74.648132, 12:23:23, 193.0, Loc-1

The first two numbers are the latitude and longitude, followed by the time, distance reading and transmitter ID.

The major power draw in the transmitter unit is the GPS receiver. The Arduino code has been written to minimise power consumption in the ATmega328P chip.

As a result, overall current drain on the battery is around 90mA, giving a battery life of around 55 hours. So as long as the solar panel gets good insolation for a few hours every two days or so, it should be able to operate continuously.

The Arduino sketch uses the built-in SoftwareSerial library plus three add-on libraries: TinyGPS, LowPower and NewPing.

These are all included in the download on the SILICON CHIP website, named "LoRa_low_power_level_sender_software.zip", which also includes the sketch itself. Install the ZIP libraries in the Arduino IDE before compiling the sketch and uploading it to the Arduino.

Remember to install the 8MHz bootloader on the Arduino before uploading the sketch, so that it will work without a crystal. Details on how to do so are at the following URL: **www.arduino.cc/en/Tutorial/ArduinoToBreadboard**

Bera Somnath,
Vindhyanagar, India. ($50)

Wien Bridge Oscillator delivers high power

This Wien bridge oscillator is capable of delivering a low-distortion sinewave with a voltage swing of more than 30V peak-to-peak (more than 10V RMS) and in excess of 500mA of output current, to drive transformers, long cables, devices with 600Ω input impedance, lamps, LEDs or other low-impedance loads. It can be built using either an OPA551 or OPA552 op amp. The key specifications of both are summarised in Table 1.

The oscillation frequency is fixed and determined by the two 16kΩ resistors and two 10nF capacitors. These set the frequency close to 1kHz. If these values are changed, both resistors or both capacitors should be changed by the same amount and the resulting frequency is roughly $1 \div (2\pi \times R \times C)$. So the frequency can be doubled by halving either the resistances (to say, 8.2kΩ) or capacitances (to say, 4.7nF).

The output amplitude is adjusted by trimpot VR1 which varies the feedback divider ratio, in combination with the incandescent lamp, which also provides amplitude stability (critical in a Wien Bridge oscillator design). It does this by acting as a more or less fixed resistance across an oscillation cycle (ie, over a 1ms period) but its resistance varies over the longer term.

Basically, if the amplitude of the oscillator output increases, current through the lamp also increases and so it heats up. This increases its resistance, reducing the closed loop gain of the oscillator circuit, thus reducing the output amplitude. As such, it provides long-term negative feedback for the output amplitude, ensuring it remains stable at the level set by VR1.

Transistors Q1 and Q2 are configured as complementary emitter-followers, to boost the output current from IC1 (which is limited to an output current of up to 200mA, for a short period) to 500mA. Q1 and Q2 should be attached to heatsinks to keep them cool.

Q1 and Q2 have no quiescent current and thus the circuit relies on the

Table 1 – key performance parameters of the OPA551 and OPA552

Parameter	Test Conditions	OPA551	OPA552
Maximum supply voltage		60V (±30V)	60V (±30V)
Gain Bandwidth product		3MHz	12MHz
Minimum gain for stability		1	5
Slew Rate		±15V/µs	±24V/µs
Settling time to 0.1%	C_L = 100pF, step = 10V	1.3µs	2.2µs
Settling time to 0.01%	C_L = 100pF, step = 10V	2µs	3µs
THD+N, 1kHz, 15V RMS	R_{LOAD} >= 3kΩ	0.0005% (gain=3)	0.0005% (gain=5)

high slew rate of IC1 to minimise zero-crossing distortion artefacts, along with the direct drive which occurs around the zero crossing from the output of IC1 via the 47Ω resistor.

Diodes D1 and D2 protect the oscillator against inductive spikes if the circuit is used to drive a transformer or other inductive load, by clipping the output voltage to the supply rails. LED1 and LED2 are connected in inverse parallel, between the output and ground with a 1kΩ current limiting resistor, so they light up when the output amplitude is above about 4V peak-to-peak (~1.4V RMS).

The output is available at CON2, with or without a 600Ω series resistor (ie, to drive a 600Ω impedance), plus three other outputs which have 10%, 1% and 0.1% of the set amplitude. Note that these additional outputs have a much higher source impedance, so are only suitable for connection to high input impedance devices such as audio amplifiers.

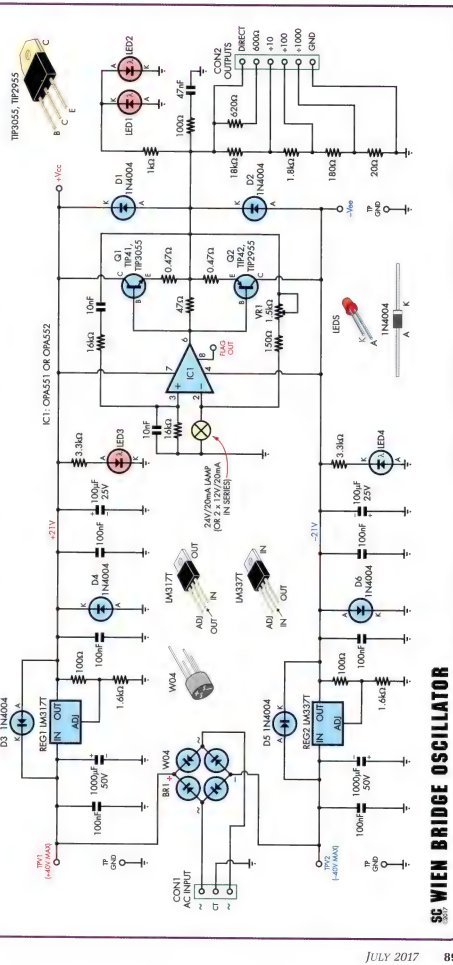
The power supply produces regulated ±21V DC supply rails for IC1, Q1 and Q2 from a 20-25VAC output transformer, or centre tapped 40-50VAC transformer, connected to CON1. The AC voltage from the transformer is rectified by bridge rectifier BR1 and filtered by a pair of 1000µF capacitors.

The resulting supply rails of approximately 26-36V DC are then regulated down to around ±21V by LM317 (positive, REG1) and LM337 (negative, REG2) adjustable regulators.

Each regulator has two 1N4004 diodes for protection, one across it to protect it against input short circuits and one between the output and ground to prevent the output being pulled negative if a single winding transformer is used to power the circuit. LED3 and LED4 indicate presence of the supply rails.

The resistors which set the output voltage of REG1 and REG2 can be changed to provide supply rails anywhere between ±12-30V DC, depending on the voltage of the power supply transformer and the required maximum oscillator output amplitude.

Petre Petrov,
Sofia, Bulgaria. ($50)



Simple constant speed controller for permanent magnet DC motors

This circuit was designed to replace the motor/driver module on a Sonab C500 stereo cassette deck.

The first attempt involved a standard motor speed control IC but this circuit was found to be better.

In a permanent magnet DC motor, in a steady state, the voltage across the motor terminals equals the back-EMF plus the voltage due to the current through the armature resistance. Motor speed is directly proportional to back-EMF in this type of motor, so it can be used to regulate the speed very accurately.

If the armature resistance is known and the motor current is measured, the voltage across the armature can be calculated and subtracted from the motor voltage to obtain the back-EMF voltage.

If the motor is then placed in the feedback loop of an op amp, the motor voltage can be adjusted to keep the back-EMF voltage constant, which is what this circuit does.

The motor current passes through a 2.2Ω shunt resistor and the voltage across this is low-pass filtered to remove switching artefacts and then fed to the non-inverting input pin 5 of op amp IC1b.

The gain of this op amp stage is set by the ratio of the 27kΩ feedback resistor and the resistance of VR2, so the gain can be set anywhere from about 1.5 times (1 + 27kΩ ÷ 50kΩ), up to 10 times or more.

Op amp IC1a controls the motor voltage via Darlington transistor Q1, connected as an emitter-follower. So the motor positive terminal voltage will be approximately 1.4V below that of IC1a's output pin 1.

IC1a's non-inverting input, pin 3, is connected to the wiper of speed control pot VR1, wired across 6.9V reference voltage VREF1. Thus, turning VR1 clockwise increases the motor voltage and speed.

Because the bottom end of VREF1 is connected to output pin 7 of IC1b, which is amplifying the voltage across the 2.2Ω shunt, a voltage proportional to the shunt voltage is added to the speed control voltage at pin 3 of IC1a. Therefore, as motor current increases, the voltage at output pin 7 rises and so does the voltage at pin 3, and thus the motor positive terminal voltage.

Now, let's say the armature resistance of this particular motor is 8Ω. Thus, with a current of 250mA, the voltage across the armature resistance is 8Ω × 0.25A = 2V and so the voltage measured across the motor will be 2V more than the back-EMF voltage.

If we adjust VR2 so that with a motor current of 250mA, output pin 7 of IC1b is 2V (ie, the gain of IC1b is set to 2V ÷ [0.25A × 2.2Ω] = 3.64), this means that this error voltage will have been completely subtracted from the motor voltage and thus VR1 will be controlling the back-EMF voltage itself.

If the motor speed drops, the feedback voltage to pin 2 of IC1a will drop and so it will automatically increase its output voltage to compensate.

Similarly, if the motor speed increases, the back-EMF and thus feedback voltage will increase and the motor voltage will be reduced. So assuming VR2 is set correctly, a steady motor speed will be maintained.

Ideally, you would measure the armature resistance and then adjust VR2 for the correct gain, keeping in mind the 2.2Ω shunt resistor value but in practice, you can simply use a trial-and-error approach.

This involves adjusting VR2 while placing some load on the motor (eg, holding your finger against its shaft, assuming that's safe) and checking to see how well it regulates the speed, then iteratively tweaking the position of VR2 to get the best result.

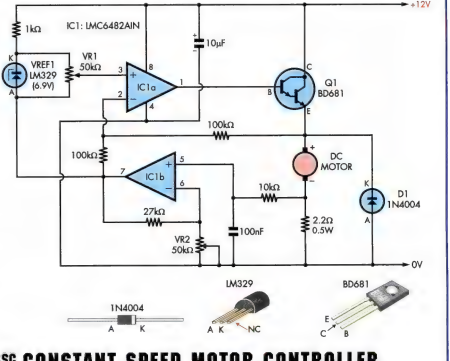
The two 100kΩ feedback resistors between the motor positive terminal, pin 2 of IC1a and pin 7 of IC1b has no effect on the feedback system, since the bottom end of the divider is also connected to the bottom end of VR1.

However, it does allow VR1 to provide a wide range of motor speed adjustments despite the fact that the voltage across VREF1 is only about half that of the 12V supply.

Note that depending on the size of your motor, you may need to change Q1 to a higher-current Darlington and/or attach it to a heatsink.

The power rating of the 2.2Ω shunt resistor should be sufficient to handle your maximum motor current; the suggested 0.5W rating is only sufficient for a motor that draws up to 475mA.

Mauri Lampi,
Glenroy, Vic. ($50)



SC ©2017 **CONSTANT SPEED MOTOR CONTROLLER**

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12V DC Cyclic Pump Timer

I have a bush shack with a 12V solar power system and a 12V pressure pump on the rainwater tank. When the Cyclic Pump Timer was published in the September 2016 issue, it seemed ideal for my system, to protect against burst pipes, except that it was designed to control a 230VAC pump (see **http://siliconchip.com.au/l/aacx**)

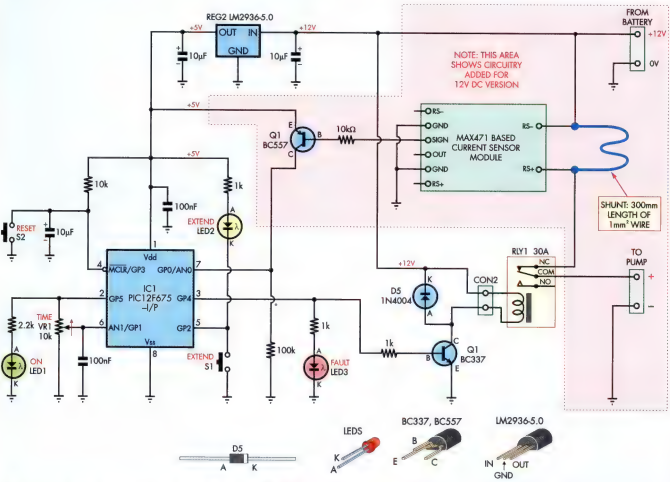
This modification adapts the circuit to control a DC pump and omits the entire 230VAC section. My pump draws about 4A which then rises briefly to about 10A as the pressure builds just before it shuts off. So I came up with a new pump current sensing circuit based on a GY-471 module containing a MAX471 high-side current sense amplifier.

This module has an open-collector logic output labelled "SIGN" which goes low when current flows from its RS- pin to RS+. I added a BC557 transistor (Q1) to invert this signal so it can then be fed to pin 7 of IC1 in the original circuit, which indicates to the micro that the pump is operating (the original circuit fed the rectified output of a current sense transformer to this pin).

The GY-471 costs just a few dollars but it has a maximum current limit of 3A through the chip's internal shunt. As there is no need to measure the current accurately, I simply paralleled its shunt with a 300mm length of 1mm^2 cross-section (1.2mm diameter) copper wire. This reduces the current through the internal shunt by a factor of ten.

Since the 230VAC-to-12V DC module has been removed from the circuit, the pump's 12V DC supply can be used to power the unit directly. The complete circuit on standby only draws 3.6mA and it functions identically to the original version. (Note: the GY-471 module is now available from the SILICON CHIP on-line shop, as well as the PCB.)

Richard Blyton,
Kambah, ACT. ($50)



SC 2017 **12V DC CYCLIC PUMP TIMER**

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to **editor@siliconchip.com.au**

By Ian Batty

DKE38 Deutscher Kleinempfänger

Germany's Third Reich produced at least two significant products to appeal to the common people. The first was the Volkswagen or "People's Car" and the second was the Volksempfänger or "People's Radio". This was followed by the smaller, more economical German Small Radio, the DKE38 Deutscher Kleinempfänger which was a 2-valve regenerative set and was manufactured by a number of German firms.

Germany, battered like most of Europe by four years of war ending in 1918, had endured barely a decade of political turmoil when the Great Depression hit the Western world.

The 1930s saw opposing political parties struggle for supremacy from which the National Socialist Party emerged. Leaving the next twenty tragic years to the historians, how was such a takeover of a modern nation possible?

Warning High Voltages!

Note that the circuit has no power transformer so it is potentially lethal to the touch since the circuit can be at the full 230VAC mains voltage. If you are working on it, you must use a 230:230VAC isolation transformer.

Apart from major political rallies, radio was an important tool in this process. Then, as now, stations could be set up at moderate cost and could, with enough power, reach every receiver of an entire country.

With government control of licensing, radio is an ideal medium for spreading ideas and opinions, for good or ill. Joseph Goebbels seems to have recognised this potential early on.

So as part of national reconstruction, ordinary people were offered two important pieces of technology we take for granted today: a car and a radio. And the People's Radio was always intended to serve political ends, at least as much as simply benefiting the population.

Both the VE301 Deutscher Volksempfänger and the DKE38 Deutscher Kleinempfänger were designed by engineer Otto Griessing, at the request of Propaganda Minister, Joseph Goebbels. The larger VE301 was a 3-valve regenerative circuit with a pentode demodulator followed by an output pentode and a full-wave rectifier for the mains power supply.

Cheap as it was, the VE301 cost around two weeks' average wages, so an even cheaper design became attractive and the DKE38 filled the bill at half the price. With a triode-tetrode (in the one envelope) doing all the "signal" work and a rectifier, the Kleinempfänger is even simpler than a set I built as a lad back in the late 1950s.

So let's check out the D(eutsche) K(lein) E(mpfänger) 38, which appeared in 1938. I've two main reasons for this investigation: how good can a radio be with just two active stages, and how can a minimal regenerative set compare with a minimal superheterodyne radio, such as the Astor DLP

I reviewed in the October 2016 issue?

The VE301 and DKE38 both cover the standard broadcast (Medium Wave) band and 145~400kHz of the Long Wave band. Both bands had been used for broadcasting since around 1920, principally for local and national broadcasts.

Some debate continues to this day over the design. Was it just a cheap-and-cheerful mate to the Volkswagen "beetle"? Perhaps the VE301 was deliberately designed to prevent owners from tuning in to politically-undesirable shortwave broadcasters such as the British Broadcasting Corporation.

Regeneration

Early valve amplifiers had been bedevilled by "howling" which was oscillation due to anode-grid feedback. Generally regarded as a curse, the effect was investigated by a young engineer, Edwin Armstrong. He seems to have reasoned that controlled feedback could greatly increase a receiver's gain.

By 1912, Armstrong had developed his regenerative technology to the point where he was able to pick up messages between San Francisco and Honolulu. Remarkably, Armstrong was in New York; well away from the intended transmission path. He also detected transatlantic signals from Ireland, a feat achieved only with difficulty by Marconi's much larger and more complex TRF receivers.

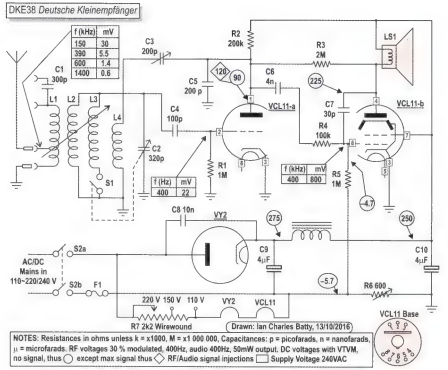
DKE circuit description

Active functions are handled by the VCL11 triode-tetrode. It has an 8-pin base most commonly seen on German metal valves. It uses a 50mA heater and while this seems very low for any heater current, the heater voltage of 90V gives an actual consumption of around 4.5W for both sections.

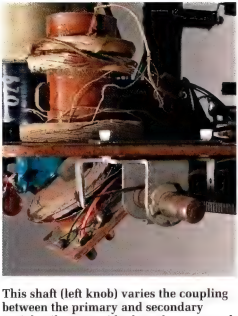
Note that the heaters of the rectifier diode and the triode-tetrode are both in series with a tapped 2.2kΩ wire resistor, R7, which enables the heater current to be correctly set to suit the incoming supply voltage.

The triode is a high-mu type, while the tetrode manages a creditable 4200 microsiemens, considering its low heater power. Note the cathodes of both valve sections are connected to pin 3.

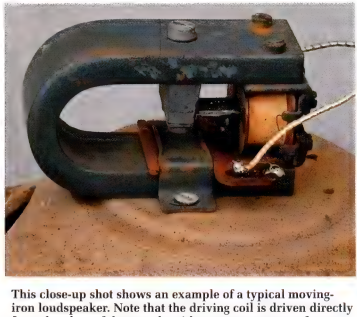
The incoming signal is tuned by L2 (in parallel with L3 on the MW setting) and variable reaction capacitor C2 and then fed to the grid of the triode via



The circuit of the Kleinempfänger DKE38 is unusual for a number of reasons: it is transformerless and therefore the chassis is live; the fuse can be in the Active or Neutral line; the loudspeaker is a moving-iron type with no transformer coupling and the bias for both valves is unconventional. The circuit also has no volume control; this is provided by varying the aerial coupling.



This shaft (left knob) varies the coupling between the primary and secondary aerial coils to provide the volume control.



This close-up shot shows an example of a typical moving-iron loudspeaker. Note that the driving coil is driven directly from the plate of the tetrode without an output transformer.

100pF capacitor C4. C4 allows grid leak bias to develop across 1MΩ resistor R1; if C4 was not present, the antenna coils would prevent grid leak bias.

The amplified signal appears at the anode and is fed back via adjustable capacitor to C3 to L4 which then couples back to L2 & L3 and of course, then feeds back via C4 to the triode grid.

This means that the grid signal is increased. If you're thinking this would make a good oscillator, you're right. It's got the potential to set up the "howling" oscillation described above. But if we carefully control the amount of positive feedback, it's possible to lift the stage gain from around 40 times to well over 100.

There's a mechanically-variable coupling control for volume acting on the aerial coil's primary. The above photo shows the tuned/reaction windings on the top side of the phenolic chassis, with the "swinging" primary winding and its control mechanism below.

Band-changing occurs when the tuning dial passes the midpoint of its rotation. LW operation uses a single secondary winding. For MW, S1 puts the second winding in parallel to reduce the total circuit inductance, just as resistors in parallel give a total lower value.

The dial is calibrated with 0-100 markings; red for LW, plain for MW. Given that tuning accuracy is affected by the regeneration setting, showing tuning frequency or station markings would not have been practical.

As well as an amplifier, the circuit is a leaky grid demodulator, ie, a diode of sorts. "Grid leak" resistor R1 is commonly 1MΩ or greater. This allows the grid to drift weakly negative. The valve will now rectify any incoming signal; positive-going signal peaks will push it to maximum anode current, negative-going peaks towards cutoff.

The net effect is much greater amplification of the negative signal peaks. The amplified signal is developed across the 2MΩ resistor R3, with filter capacitor C5 partially filtering the RF component in the process of demodulating the audio, which is then fed to the grid of the output tetrode via capacitor C6 and resistor R4.

The output stage's grid bias is developed across R6, a factory adjustment which sets the output stage's anode current. It's a classic back bias arrangement and not, as described in one online article, designed to reduce HT supply hum. The bias is fed to the grid via resistor R5.

Some confusion exists regarding coupling components R3, C7, R4 and C6. Taking C6 first, it's the usual coupling capacitor from the driver to output, in this case from the triode's anode to the tetrode's grid.

R4 would usually be a stopper resistor, placed so that it damps parasitic oscillations in the tetrode. But here, it appears in combination with 30pF capacitor C7.

Ineffective at audio frequencies, C7 provides negative feedback at above-audio frequencies to filter out any of the original RF carrier from the output audio. R4 is needed to prevent C7's feedback affecting the demodulator's RF operation.

R3 provides conventional negative feedback from the output stage's anode back to the demodulator and thus to the output grid.

Moving-iron loudspeaker

The loudspeaker requires special mention. For a start, it is a moving-iron arrangement, with the cone attached to an iron pole-piece instead of a voice coil, as in a conventional dynamic speaker.

Second, it has a very high DC resistance of 2kΩ and an even higher impedance of 17kΩ at 1kHz, which means that this can be driven directly from the tetrode's plate rather than using an output transformer. The plate current flows through the loudspeaker's field coil but it is only 12mA and not likely to cause much additional distortion.

The pressed cardboard "basket" may seem pretty agricultural, but it does not need the steel basket we see used in dynamic speakers (needed to hold the voice coil, magnet and cone in alignment).

The moving-iron type's "motor" contains all parts except for the outer rim of the cone. Since this outer rim does not need precise positioning, the pressed-cardboard basket gives adequate strength and stability while economising on costly steel. Eliminating the output transformer also saved steel and wire; highly necessary in pre-war Germany.

The moving-iron speaker can also use a high-impedance winding that matches directly to the output valve. This eliminates the costly and bulky output transformer needed for

matching to the low voice coil impedances of dynamic speakers.

The lack of a power transformer has already been mentioned. One side of the mains supply is fed through the double-pole switch S2 to the anode of the rectifier diode, VY2.

The output from the cathode feeds a standard pi filter, with two 4µF capacitors, C9 & C10, together with an iron-cored choke. R6, between the negative terminals of the two capacitors, develops the back bias for the grid of the output tetrode, as mentioned above. C8, across the diode, is there to reduce rectifier buzz.

Appearance and controls

The DKE38 has a very spartan Bakelite cabinet with simple controls: the left-hand knob, volume, adjusts the coupling between the aerial coil primary and its tuned windings.

The central tuning control tunes either the Long Wave or Broadcast bands, with the change-over occurring at the middle of its 360° travel. The right-hand "regeneration" control adjusts feedback from the triode's anode to a regeneration winding on the aerial coil assembly.

The set is constructed on a fibre composite chassis with point-to-point wiring. It's pretty much a double-sided breadboard radio. My set's mains cord anchoring consisted of one mains wire doubling through a hole in the chassis – not even close to safe.

The top view of the chassis (on the last page) shows the 8-pin VCL11 socket at top left, above the aerial coil. The VY2 rectifier socket is towards the right, above the filter choke with the two main filter capacitors at the right-hand edge. The tuning capacitor occupies the lower centre.

Original parts are easily spotted: any large enough to be branded bore the Reichsadler "Imperial Eagle" symbol. The underside view shows the aerial coil at lower right, with the large tuning knob in the centre. Minor components are wired point-to-point under the fibre/composite chassis.

The aerial coil primary offers two tappings for different lengths of aerial wire, with a third connection via 300pF capacitor C1. The adjustable regeneration and tuning capacitors both use plastic dielectrics.

This makes them compact but also easier and cheaper to manufacture than air-spaced versions which must be made to high precision to preserve plate spacing. There's a bonus for the tuning capacitor – it can rotate through a full 360°, allowing the set to change bands (as noted below) simply by turning the knob past the end of the current band.

The DKE38 shown with the original moving-iron loudspeaker. Note the vertical tapped resistor which is used to set the filament current in the rectifier and the triode-tetrode. The preset control is R6 which was adjusted by the factory to set the back bias for the tetrode section.

The picture directly below shows the "flat" solid-dielectric tuning capacitor on top of the chassis, with its tuning knob below. The band-change contacts are just visible on top of the tuning capacitor. The vertically mounted reaction capacitor is on the right-hand side with its tuning shaft pointing forward to pass through the front of the case.

Making it work

As purchased, the physical condition

This shot shows the tuning knob which covers the LW and MW bands. The knob on the right is the regeneration control.

This underside view of the set shows that it is a non-metallic chassis. This causes problems when using any of the controls, because of hand-capacitance effects.

of the set was good, although the chassis was understandably dirty and dusty. A brush had little effect, so I turned to one of those microfibre kitchen scourers. Used dry, it cleaned off all the dust and left a light polish on the fibre composite chassis.

The Bakelite cabinet was shiny with no noticeable blemishes, it had the original knobs, and the Reichsadler emblem was undamaged. You'll find some examples where that emblem has been defaced, presumably due to its association with the Nazi Party. A second set, bought while this article was in preparation, was defaced. However, I used it for some internal photos as it's pretty well original.

Electrically, the review set had been restored "to some extent". Many components had been changed and the original moving-iron speaker had been replaced by an oddball dynamic speaker of some 300Ω impedance and a 3600Ω series resistor. Not surprisingly, I couldn't get a peep out of it. A junkbox 240~30V transformer gave a pretty good match for the substitute speaker and I was able to get some operation.

I also noticed a 200pF capacitor connected between the Earth connection on the aerial socket bar and the "low" side of the mains. I'm guessing this was to capitalise on mains earthing and eliminate the need for a separate earth wire. Be aware that, if such a capacitor fails (or even becomes leaky), you've got a 50-50 chance of putting your aerial system at lethal 230VAC mains potential.

Even so, the set still didn't work as well as I expected, so I popped in a spare VCL11 I'd bought some time ago. Then it was time to take it for a test drive. All measurements were made with an isolating transformer and a 220VAC supply, as I didn't want to stress this rare set with the full mains voltage.

So how did it go? For a set made some 80 years ago, with just two active elements; pretty well. But if you're expecting "superhet convenience", you'd be disappointed.

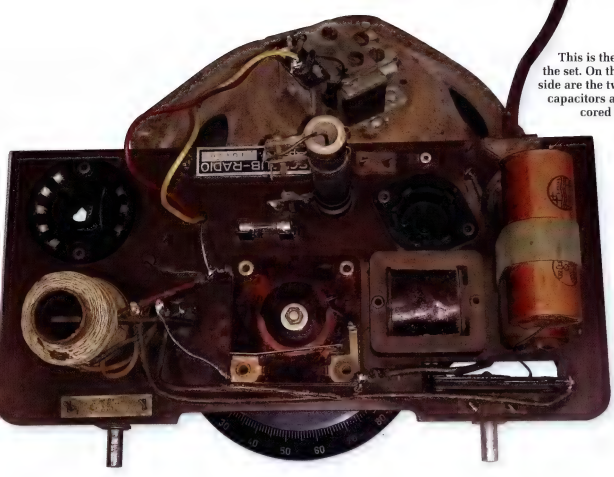
At maximum sensitivity, the Kleinempfänger suffers from hand capacitance effects when tuning or adjusting it – the Bakelite case and chassis simply can't provide the levels of grounding and shielding we take for granted with a metal chassis. This set also demands careful adjustment for optimal performance.

I measured the sensitivity first. Using the standard dummy antenna between my signal generator and the set, for 50mW output, the LW band needed 25mV at 145kHz, and 3.5mV at 400kHz. For the MW band, it was 1.4mV at 600kHz and 600μV at 1400kHz. Removing the dummy antenna improved the 150kHz sensitivity to 600μV, implying that actual performance will depend on aerial wire length.

As expected, bandwidth varied with the degree of regeneration. For the LW band at 145kHz, it was only a few hundred Hertz at full regeneration and ±800Hz with a 10dB reduction. At its top end (400kHz), full regeneration gave a bandwidth of ±800Hz, with a 10dB reduction giving ±1200Hz.

For the MW band, full regeneration 480kHz bandwidth was under ±200Hz (really!) and ±500Hz at reduced regeneration. At 1630kHz it was ±3900Hz and ±7900Hz respectively.

These figures reinforce the general problem with Tuned Radio Frequency sets of all kinds: bandwidth varies drastically with tuning and regeneration simply exaggerates the effect. At the low end of the MW band, just at the point of oscillation,



This is the top view of the set. On the righthand side are the two 4µF filter capacitors and the iron-cored filter choke.

radio broadcasts sound like they're coming down a drainpipe.

What if we eliminate regeneration? Disconnecting it completely demanded some 270mV of input at 600kHz for 50mW out. Remembering that optimal adjustment gave 50mW out for only 1.4mV in, this implies a "regeneration gain" of up to 200 times; as much as an extra (very good) RF amplifier. It's evidence of Armstrong's revolutionary improvement to receivers in those long-ago "pre-superhet" days.

What about responses to signal strength? Output rises from zero signal to a certain level (depending on aerial coupling and regeneration), then flat-lines. For a 50mW output setting, I could increase the input by some 50dB and get no significant rise in output power.

What's happening here is that, as signal rectification increases grid bias, anode current and thus stage gain both fall off as the input signal increases. In circuit, there's a marked rise in the triode's anode voltage with rising signal strength.

Audio performance will depend partly on the speaker (for a moving-armature type) or on the output transformer for a dynamic speaker. Using a representative output transformer, the low-frequency –3dB point was 130Hz. High-frequency response varied greatly, as the RF bandwidth figures indicate. High-frequency response is markedly reduced at maximum regeneration.

Maximum audio output varied frustratingly with aerial coupling, tuning and regeneration. The best was some 140mW but a more reliable clipping figure of 100mW gave some 10% THD (Total Harmonic Distortion).

While 100mW is much less than the customary valve mantel with a 6V6 output stage, it's comparable to many transistor mantels such as the Astor M5.

At 50mW output, THD was around 5%, about 7% at 10mW output. Direct audio injection gave a maximum output of some 500mW with visible distortion. In practice, it reaches 10% THD at around 200mW.

Is it as good as the Astor DLP? The answer has to be no. The DKE38 is not as sensitive, its audio response varies widely, it has lower audio output and is much harder to get the best results from. The DKE38 makes the case for the combination of superhet circuitry and ganged tuning capacitors.

Would I buy another one? During this project, I did. It came at a good price but with one drawback. Otherwise pretty original (including the speaker), it had its Reichsadler symbol defaced, as noted above. You can expect to pay upwards of $1,000 for an all-original, working DKE38.

All told, the Kleinempfänger DKE38 is a remarkable piece of minimalist engineering, and one of the last regenerative sets made in large numbers and offered for sale to the general public.

Further reading

Ernst Erb's Radiomuseum has an extensive collection of circuit, photos and German-language operating manuals. Go to the home page and enter DKE38 into the search bar:

www.radiomuseum.org/

There's an extensive article on Phil's Old Radios:

http://antiqueradio.org/KleinempfaengerDKE38.htm

I've focused on the DKE38's technology in this article. For a reminder of its actual political environment, with examples of propaganda posters, try Phil's Old Radios on the VE301:

http://antiqueradio.org/VolksempfaengerVE301dyn.htm SC

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PIC programming questions

I have downloaded MPLAB 8.92 which seemed to be the up-to-date version to use to program the PIC-32MX170 for the Micromite (www.siliconchip.com.au/Project/Micromite). The MPLAB downloaded and installed, even downloading some support files! I was going to use this program with a PICkit 3.

On checking the configuration, I could not find the device PIC-32MX170. The devices listed went from MX150 to MX210 (plus other letters). I tried searching for updates of the main program and ways of updating the data. Unfortunately, I couldn't find anything to help me. After several hour of frustration, I thought I need to ask for help.

I must be jinxed with programming PICs as I tried to get the programmer from May 2008 (www.siliconchip.com.au/Article/1824) to work but WinPic didn't want to cooperate back then, but it did give me the idea to use an IC socket into which a ZIF socket is used for holding the PIC to be programmed, as per the old Jaycar kit.

I also want to try programming a PIC using an Arduino, as described in the November 2015 article titled "Cheap programmer for the PIC32 microcontroller" (http://www.siliconchip.com.au/Article/9403). So, I have a question on that, too. I have downloaded and I think installed the pic32prog successfully from GitHub but when I try to open it I get a small window opening up and then it disappears. Is this because I haven't opened a command window? How do I do that on XP/Windows 8.1? (R. P., via email)

- The latest version of MPLAB is MPLAB X v3.61.

It's likely that you will not get support for the PIC32MX170 without using MPLAB X, which superseded earlier versions of MPLAB such as the 8.xx versions.

Regarding your second question; yes, you need to run pic32prog from a command prompt. In Windows XP, you can open one by going to the Start menu, selecting the Run option and then typing "cmd" and pressing enter.

In Windows 10, Microsoft changed the way the "Start" menu works; it doesn't seem to be called that any more but it works similarly. Simply click the button in the lower-left corner of the screen to open the menu, type "cmd" and press enter. Windows 8.1 should operate in a similar manner.

Alternatively, in Windows Vista and later, you can hold shift and right-click in a folder to give you the menu option to open a command window in that folder.

Majestic speaker dimension misprint

I am currently building several of the Majestic speakers (www.siliconchip.com.au/Series/275) but I am confused about the hyperbolic horn construction.

The follow-up article in the September 2014 issue shows different dimensions for the horn panel in Fig.3 but the panel still seems to be too long to be secured at the critical points of attachment. I am assuming that the length of 660mm as stated may be a typo as is the front anchor point of 377mm. (R. L., Cornubia, Qld)

- The figure of 377mm on the diagram on page 89 of the September 2014 issue is a misprint; it should be 37mm, as in the original diagram on page 27 of the June issue. Thank you for bringing it to our attention. The dimension of the curved horn panel is correct at 660mm. The misprint has been corrected in the online issue.

Stationmaster frequency lower than expected

Recently I finished building your Stationmaster train controller, published in the March 2017 issue (www.siliconchip.com.au/Article/10573). However, it does not work and I'm wondering if you can help me troubleshoot it?

The red LED comes on when DC or AC is applied but when trimpot VR1 is turned, no other LED comes on. I have followed instructions in the magazine and the voltage across V_{CC1} and V_{CC2} is correct but when the frequency is checked across SYNC, it only comes up with 50Hz, not the required 8-10kHz. (A. M., Lidcombe, NSW)

- The SYNC output seems to be open-circuit if you are only picking up mains

LED downlights

I am replacing some Kogan LED downlights in my kitchen with Philips units since the Kogan ones produce too much RF interference (see related letter in Mailbag in this issue). I have eight of these halogen-replacement downlights that I want to combine.

I know that LEDs need DC but these downlights are non-polarised; they just plug in to where halogen lights were previously. I could make up a 12V DC supply to power the lot but aren't the downlight transformers that you get from electrical suppliers AC only? Does that mean that each LED has its own rectifier in-built?

Perhaps I should buy 12V transformers from Bunnings and just wire the LEDs in parallel, making sure that the combination is well within the ratings of the transformer(s). (I. S., Glenhaven, NSW)

- Any LED that is intended as a plug-in replacement for a 12V halogen lamp will have its own built-in rectifier and current drive circuitry so they can run from the original 12V AC transformers. A single 12V 50VA transformer should easily handle all eight LED lamps.

Adding over-current protection to Speaker Protector

Could over-current protection be added to the next version of SILICON CHIP's excellent speaker protector from the November 2015 issue (www.siliconchip.com.au/Issue/2015/November/A+Universal+Loudspeaker+Protector)?

This would mean that if someone accidentally shorted the speaker cables, the speaker protection will detect the huge voltage drop across the amplifier's emitter resistors and then the relay will be switched off.

One added resistor can be used to define the speaker impedance, so if the speaker's impedance is below 6Ω, the protection circuit will refuse to turn on the relay.

This way we are protecting an amplifier that is designed to work with 6 to 8-ohm speakers from a load of significantly lower impedance (eg, if a 4Ω or 2Ω speaker is connected instead).

- At first sight, this could be a useful enhancement, even though it would a bit tricky to do without the potential for false tripping, as the impedance of all speakers can dip well below the nominal value. For example, an 8Ω speaker can definitely have an impedance below 4Ω at certain frequencies.

You might consider using a microcontroller or some tricky circuitry to pass a small AC signal through the speakers at switch-on to detect the impedance at a few different frequencies and decide whether to switch the outputs off or not.

However, the more one considers the idea, the less desirable it becomes, especially if we add a series resistor, as you suggest, to "define" the speaker impedance. Any such resistor will degrade the damping factor of the amplifier and possibly also degrade the overall distortion performance.

We take the view that any amplifier should be capable of coping with the inevitable dips in the impedance curve at some frequencies, for all loudspeakers. That means it should cope with very brief signal bursts at those critical frequencies without any interruption to the output signal.

Even a brief short circuit between the outputs of an amplifier should not cause any problems, particularly if the signal level is low. Of course, much longer severe overloads, which might happen when the amplifier is really cranked up to high volumes, should be protected by the supply fuses blowing.

radiation on your frequency meter (the most likely explanation for a reading of 50Hz). Check at pin 7 of IC1 directly. Make sure IC1 has 5V at pin 4 and 0V at pin 11. This oscillator should work if the components are correctly placed and soldered in with no dry joints.

The voltage at pin 2 and pin 5 of IC1 should be at half supply, ie, 2.5V.

Deep Cycle Battery Charger confusion

I have built the Deep Cycle Battery Charger described in the November and December 2004 issues of SILICON CHIP (www.siliconchip.com.au/Series/102).

However, there appears to be an anomaly in the connections to bridge rectifier BR2. The circuit diagram shows no connection to the negative pole of the rectifier but the board layout shows it connected to the battery negative terminal. Could you please clarify which is correct. (G. C., Stanthorpe, Qld)

- We can see the source of your confusion; the PCB overlay for that project in the December 2004 issue is labelled in a confusing manner. Referring to the PCB overlay on page 31 (Fig.6) and the wiring diagram on page 33 (Fig.9), the terminal labelled "TO BR1 NEGATIVE OUTPUT" in Fig.6 does indeed go to the negative output terminal of BR1, as shown in Fig.9.

However, the terminal labelled "TO BR2 NEGATIVE OUTPUT" in Fig.6 actually goes to the AC terminals of BR2, as shown in Fig.9. These effectively act as the negative output in this case, even though they are not labelled "-". That's because only half of the diodes in the bridge rectifier are used.

So the PCB overlay and wiring diagram are consistent with the circuit diagram in the November 2004 issue, as long as you understand that the "negative output" of BR2 is not actually the terminal marked "-" in this case.

Quirks encountered with Micromite tutorial

I have just completed the Micromite LCD BackPack project from the February 2016 issue (www.siliconchip.com.au/Article/9812) but I am having a few issues that I hope you might be able to help me sort out.

I am a total novice when it comes to these little microprocessors and any programming, although I did have a go with BASIC when I was in high school, with a DSE VZ200 computer!

I was prompted by the articles on getting started with the Micromite in the February, March, May and June 2017 issues (www.siliconchip.com.au/Series/311). I was considering the Arduino or Raspberry Pi platforms but choose the Micromite as it is a local product and hopefully help is not too far away.

I have it up and running and configured as per the February 2016 article. The screen is calibrated, the touch/draw functions work etc.

However, when I write out the test program for the clock/calendar in MMEdit and attempt to run it, it loads the program, acknowledges the Micromite and then I get the error message "DO WITHOUT LOOP", even though I have typed the program exactly as printed, including the loop command at the end.

I then thought I'd make up the little diode & resistor circuit and connect the anode via a 470Ω resistor to pin 14 and the cathode to GND and run the little program on page 20 of the February 2017 issue.

The result of this is an error message "pin 14 reserved at start up". I am using MMEdit version 3.69 and Terra Term Version 4.93 on a Windows 10, 64 bit desktop computer. I am using the PIC32MX170F256B-50I/SP which I programmed myself with a PICkit 3.

As I sit here typing this note I have the screen constantly drawing those lovely little coloured circles of the GUI TEST LCDPANEL command.

I am using the same Serial to USB converter as in the article and it seems

Fixing incorrectly sized Senator speaker cabinets

I had a cabinet maker supply and cut out the panels using the dimensions given in the Senator loudspeakers article from September 2015 (www.siliconchip.com.au/Series/291).

But I forgot about the later correction to the cabinet size with the result that the cabinet maker made the width 320mm. He very cleverly almost matched the depth and height, but the width was left at the 320mm.

If my calculations are correct, I now have enclosures that are 4.63 litres too large. If memory serves me correctly from previous articles on vented enclosure design, this is a significant variation to design parameters.

It cost a packet to get the cabinet maker to supply and cut the imitation-wood coated MDF and this used my allocated budget for this project (which is why I built the budget Senator).

Would adjusting the box/port resonance frequency to match this different volume be easier than rebuilding the boxes?

Without doing the maths (which I could use some help with – I don't have software to do it for me), can you suggest a box/port resonant frequency to match my slightly larger cabinet volume?

When I refer to the box/port frequency I'm assuming this means only changing the port length, which would be the easiest option.

Alternatively, can you recommend some open-source software I can use to do the required calculations? In case it helps, here are the exact dimensions of each panel cut:

* Front and rear baffle: 730mm x 315mm
* Side panels: 730mm x 414mm
* Top panel: 347mm x 414mm
* Bottom panel: 315mm x 382mm

Another difficulty created by the cabinetmaker was that they only used 16mm MDF. Thinner MDF means I'll need some small-volume bracing which may restrict me to using aluminium angle.

If I used MDF for bracing, some close calculations of volume would be needed. A cross-brace in 16mm MDF would be 16x315x100 which works out to 0.5 litres if I used a 100mm width. I hope Allan Linton-Smith won't be too horrified. (E. McA, Capel, WA)

● By our calculations, the change in volume is just over one litre which means that there should be negligible change in performance.

We calculated this by ignoring the overall cabinet dimensions and just using the internal dimensions. The published cabinet is 73 × 32 × 38.1cm = 89 litres, while your cabinet is 73 × 31.5 × 38.2cm = 87.84 litres

A small amount of added bracing would be unlikely to have much effect.

to work fine. Here is the program I'm trying to run. Where am I going wrong? (P. C., Woodcroft, SA)

```
CLS
BOX 0, 0, MM.HRes-1, MM.VRes/2,
  3, RGB(RED), RGB(BLUE)

DO
 TEXT MM.HRes/2, MM.VRes/4,
  TIMES, CM, 1, 4, RGB(CYAN),
  RGB(BLUE)
 TEXT MM.HRES/2, MM.VRES*3/4,
  DATE$, CM, 1, 3, RGB(GREEN)
 IF TOUCH(X) <> -1 THEN END
LOOP
```

● We tried typing in the same sample program (from Fig.6 on page 28 of the February 2016 issue) into MMEdit, just like you, and we too got the "DO WITHOUT LOOP" error.

However, as you say, the LOOP line is there so we tried doing exactly the same thing again from scratch and would you believe it worked the second time? We're quite baffled by this and we think maybe it is a bug in MMEdit which somehow mangles the code when it is first uploaded to the chip. So please try again.

Note that we've had other readers complain of the "DO WITHOUT LOOP" error however they were trying to type the program directly into the console.

The error is produced as soon as you type the "DO" line in that case. You need to use the Micromite's built-in EDIT command, or MMEdit, to enter the sample program (or any program, for that matter) as commands entered in the console are executed immediately.

As for the program on page 20 of the February 2017 issue, that was intended to be used on a bare 28-pin Micromite. Your LCD BackPack is already using pin 14 to communicate with the LCD (it's the SPI IN pin).

You have two options: either disable the LCD to free up the pin or change the code to use a different pin. The latter is probably easier. Pins 4, 5, 9, 10, 16, 17, 18, 21, 22, 24 and 26 are all available.

It's unfortunate that the example in the tutorial uses pin 14 when it won't work on the LCD BackPack. Had we realised, we would have changed it.

To solder the pad on the underside of SMD ICs?

I am currently building your Compact 8-digit Auto-Ranging Frequency Meter project from the August 2016 issue (www.siliconchip.com.au/Article/10037).

On inspection of the surface mount ICs1-3 (ADA4899 high speed op amps), I noticed that they have a pad on the underside in the middle and so does the circuit board, with a plated-through hole.

Do I need to solder that pad of the circuit board from the underside? The instructions of how to solder the ICs don't mention it. Or do I have to put pressure on the IC, so there is contact? Is this pad perhaps used as a heatsink? I would appreciate your help.

On another note, I purchased the Banggood DSO138 scope kit, described in the April 2017 issue (www.siliconchip.com.au/Article/10613). That is a terrific little project and proved easy and fun to build. Thanks for presenting it and I am looking forward to more of your excellent technical articles.

And to the readers who think this or that article does not belong to an electronics magazine, if you can learn something then it is definitely worth having it! (H. M., Bowral, NSW)

● You are right, the article left out mention of soldering the pad on the

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PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)
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6/17

Down button not working on Digital Audio Signal Generator

I've been building the Digital Audio Signal Generator from the March, April & May 2010 issues (www.siliconchip.com.au/Series/1) and have finally gotten it to power up.

The problem I have struck is that I cannot get the down button to work. I have tried many things and traced the circuit right through from the main board. No luck, except when I stopped the select button from being in the circuit. Then it would go down but it would only go down a menu item, not take a value down!

All the other buttons work as they should. I need to have the down button working so I can have one channel at 1000Hz and another at either 500Hz or 2400Hz. Unfortunately, you cannot use the Up button to take it back to zero as it stops at 24000Hz. You then have to switch off and restart.

I also had a lot of trouble with ZD1 and trying to get one that came close trying 4.7V and 5.1V units from many suppliers. They vary so much, even within a batch. I have finally found some with a rated breakdown voltage of around 4.9-5.0V and am going to get some and try them.

At present, it's close and works alright with correct voltages at 7.0V DC. If I go above that by 0.3V, the screen starts to get an orange background!

Except for the button issues, the PIC appears to be doing its job and I was very careful installing it. I would really appreciate any assistance you can give me in this as it's not much use at present and I really need the analog side to work properly. (P. N., Newtown, Qld)

- This is quite baffling. Our prototype certainly didn't exhibit button problems like you describe, but you say you've checked the continuity between the buttons and the micro and that would have been our first guess as to the problem.

Normally we would recommend you try replacing D9 and D11, carefully check the solder joints for D9, D11, S5, S7 and CON9 on the front panel board and CON4 on the main board, and make very sure that the ribbon cable connecting the two boards has been properly crimped.

In the past, the ribbon cable has been the source of most faults. The crimp connectors can look good but you can have a high-resistance connection to one or more pins. In that case, it's worthwhile re-crimping both ends just to make sure.

It's especially weird that you managed to get the Down button to work in the menus but not for changing values.

It seems like it might be a timing problem but we can't understand why. Maybe try a different PIC. As you purchased the original PIC from us, we could send you a replacement on the basis that it seems to be faulty.

underside of these ICs. This was intentional because we found it was quite easy to allow too much solder to flow through the hole and this can short out the pins, which is then difficult to fix.

It isn't critical to solder this pad; it does improve the chip's heatsinking but in our circuit, they are not dissipating so much power that it's an issue.

These ICs are designed to be used with hot air or infrared reflow soldering, where solder paste is placed on the PCB, then the IC is placed on top and it is heated to melt the solder paste. You can use this same approach if you have a hot air rework station. They are available at surprisingly reasonable prices.

The hole we placed on the PCB is large enough to fit a very fine soldering tip through and solder the bottom side of the IC directly. However, this should not be necessary.

If you put a little flux paste under the IC before soldering it in the usual way, then add a little extra flux paste into the hole on the other side, simply applying solder to the pad on the underside should cause it to flow through the hole and onto the pad on the bottom if the IC.

If you decide to do this, be careful to only add solder sparingly, though, to avoid the aforementioned possible short circuits.

Using VK2828U7G5LF GPS module

I am building the High Visibility 6-Digit LED GPS Clock (December 2015 & January 2016; www.siliconchip.com.au/Series/294) and the Deluxe GPS 1PPS Timebase for Frequency Counters (April 2013; www.siliconchip.com.au/Article/3757), both using the VK2828U7G5LF GPS module purchased from your online shop (www.siliconchip.com.au/Shop/7/3362).

Is a pull-up resistor needed from the +V line (red wire) to the enable line (yellow wire) or can the enable line be connected directly to the positive supply? What value for such a resistor do you suggest? Is it best to use 3.3V or 5V to power this module? (R. P., via email)

- It will work either way, with a pull-up resistor from +V to EN or with a direct connection. As long as the EN pin (yellow wire) is pulled high, the module should operate. If you do use a resistor, we suggest something in the range of 1-10kΩ.

We tested it at both 3.3V and 5V and didn't notice any difference in performance. Its I/O signal swing is 3.3V regardless of the supply voltage. Note though that 5V is recommended and 3.3V is the specified minimum, so unless your 3.3V rail is precisely regulated, a 5V supply is a little safer.

If you run the module off 3.3V that is derived from 5V via a linear regulator, you will be increasing dissipation in the regulator and also reducing the 3.3V current available to the rest of your circuit.

Alternatively, if your 3.3V rail is derived via a switchmode regulator, overall power consumption will be lower than if you power the module from 5V.

So we suggest using a 5V supply unless there is a compelling reason to do otherwise, but our tests suggest it will run off 3.3V just as happily.

Personal Noise Source wanted

I am after an old kit from the September 2001 issue; the Personal Noise Source, PCB code 01109011. Is it still available or would I have to make it? (G. M., Kogarah, NSW)

- Unfortunately, we do not have PCBs

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for this project. You can purchase a PDF of the artwork from our website if you want to make the board. But have you considered that there are pink noise apps for smartphones? That really seems like a more convenient solution, unless you don't want to use a smartphone.

Large LCD panels for the Explore 100

I'm currently building the Explore 100 project (September & October 2016; www.siliconchip.com.au/Series/304) and have a query regarding the LCD panels that are suitable.

On page 79 of the September 2016 issue, under display size and in bold print, it says that the East Rising panel uses a non-standard interface pin-out.

Does this only refer to the 8-inch panel or the 5-inch and 7-inch panels as well? I would like to use the largest panel that has the standard interface pin-out. (I. T., Blacktown, NSW)

● Geoff Graham replies: East Rising is a company that does not necessarily follow established standards, so you need to have a good depth of knowledge and flexibility when using their products.

The article mentioned the East Rising 8-inch display as that is the only 8-inch display that we could find and that we tested.

If you are considering 5-inch and 7-inch panels then you would be better going with more standard eBay products that will plug straight into the Explore 100. These two examples look OK (note that we have not tested them so we cannot guarantee anything):
http://siliconchip.com.au/l/aad1
http://siliconchip.com.au/l/aad2 SC

Next Month in Silicon Chip

LTspice - simulating and testing circuits, part 2

Next month in part two of our SPICE tutorial, held over from this issue due to space constraints, we describe how to build a basic simulation of a relay in LTspice. We then make the relay model more realistic by adding a few extra features.

El Cheapo Modules, part 8: GPS modules

We describe two common GPS modules, their features and how to interface them to an Arduino or Micromite.

Survey of Radio Telescopes

Silicon Chip has had a number of articles on radio telescopes, the most recent being on China's gigantic new telescope, in the October 2016 issue. Now Dr. David Maddison takes a look at radio telescopes around the world, from the relatively small to the extremely large which use the techniques aperture synthesis and interferometry.

Using a DDS Module for AM Radio IF Alignment

In this article, we present updated software and slight tweaks to the hardware of the Micromite BackPack Touchsreen DDS Signal Generator described in the April issue. These changes make it a cinch to align the IF stage of a transistor or valve-based superheretodyne AM radio.

Rohde & Schwarz RTB2004 DSO Review

We take a look at this latest offering from R&S which combines a 10-bit ADC and 10.1-inch capacitive touchscreen along with either two or four channels in a compact bench-top unit.

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The August 2017 issue is due on sale in newsagents by Thursday July 27th. Expect postal delivery of subscription copies in Australia between July 27th and August 10th.

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Notes & Errata

Improved Tweeter Horn for the Majestic Loudspeaker, September 2014: Fig.3 on page 89 has a misprint in the printed edition, which shows a distance of 377mm between the front of the lower panel of the speaker and the end of the hyperbolic horn panel. It should read 37mm instead. The online version of this article shows the correct dimension.
Spring Reverberation Unit, April 2017: if using the DC supply option with CON6 (the barrel connector), it's necessary to either omit CON5 and solder a short length of wire between its two outer mounting holes (without shorting to the centre), or alternatively, fit a 3-way connector for CON5 and connect a wire link across its two outer terminals.
6GHz+ RF Prescaler project, May 2017: As published, this project does not have an output impedance of 75Ω; it is 300Ω. This can be fixed by substituting 0Ω resistors for the 100Ω resistors and 75Ω resistors for the 300Ω resistors.

WARNING!

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